1959.

THE PARLIAMENT OF THE COMMONWEALTH OF AUSTRALIA.

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OF THE

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

FOR

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Commonwealth Scientific and Industrial Research Organization.

ELEVENTH ANNUAL REPORT FOR YEAR 1958-59.

I. INTRODUCTORY.

1. General.

The Commonwealth Scientific and Industrial Research Organization was established in 1949, when the Science and Industry Research Act 1949 was proclaimed. Under that Act the Organization took the place of the existing Council for Scientific and Industrial Research, which in 1926 had taken the place of the former Institute for Science and Industry.

The powers and functions of the Organization include: The initiation and carrying out of research in connexion with, or for the promotion of, primary and secondary industries in the Commonwealth of Australia, or any territory of the Commonwealth of Australia, or in connexion with any matter referred to the Organization by the Minister; the training of research workers; the making of grants in aid of pure scientific research; the establishment of scientific research studentships and fellowships; the establishment of research associations for carrying out industrial scientific research; the testing and standardization of scientific apparatus and instruments; the carrying out of scientific investigations connected with standardization; the collection and dissemination of information relating to scientific and technical matters; the publication of scientific and technical reports and periodicals; and acting as means of liaison with other countries in matters of scientific research.

2. Executive.

Dr. S. H. Bastow, D.S.O., B.Sc., Ph.D., Chief Executive Officer, has been re-appointed to the Executive for a period of five years.

Mr. A. W. Coles has been re-appointed to the Executive for a period of three years.

Dr. J. Melville, M.Sc., Ph.D., F.R.A.C.I., Director of the Waite Agricultural Research Institute, has been appointed to the Executive for a period of three years. Dr. Melville fills the vacancy caused by the resignation of Mr. H. J. Goodes.

The Minister, the Right Honorable R. G. Casey, invited the Treasurer to nominate an officer of the Department of the Treasury to attend meetings of the Executive. Mr. L. B. Hamilton (Acting First Assistant Secretary) was appointed to fulfil this function.

3. Advisory Council and State Committees.

The following members retired from the Advisory Council during the year:—

- Professor W. V. MacFarlane, M.A., M.D. (Chairman, Queensland State Committee).
- Mr. T. A. Frankcomb (Chairman, Tasmanian State Committee).
- Mr. A. B. Ritchie, M.A. (Co-opted).
- Professor A. D. Trendall, M.A., Litt.D. (Co-opted).
- Dr. A. R. Callaghan, C.M.G., D.Phil., B.Sc., B.Sc.Agr. (Chairman, South Australian State Committee).

The following new members have been appointed to the Council:—

- Professor A. E. Alexander, M.A., Ph.D., Sc.D. (Co-opted).
- Mr. R. S. Wilson (Chairman, Queensland State Committee).
- Professor H. N. Barber, M.A., Ph.D. (Chairman, Tasmanian State Committee).
- Professor J. G. Wood, Ph.D., D.Sc., F.A.A. (Chairman, South Australian Committee).

The term of office of the State Committees ended on 31st December, 1958. Some changes in membership occurred when the Committees were appointed for the three-year period ending on 31st December, 1961.

4. Death of Sir Ian Clunies Ross.

Sir Ian Clunies Ross, Chairman of C.S.I.R.O., died in Melbourne on 20th June, 1959. He had been associated with the Organization or its predecessor since 1926, when he was appointed to the C.S.I.R. as a parasitologist. In 1931, he became Officer-in-charge of the McMaster Animal Health Laboratory, Sydney. In 1946, he joined the Executive Committee of the C.S.I.R., and in 1949 when the Council was re-organized as C.S.I.R.O., he became its first Chairman.

The high regard in which the work of the Organization is held is due largely to his constructive leadership, breadth of outlook, and wise guidance. He devoted himself unsparingly to his work for science and through his activities made the research work of C.S.I.R.O. widely known throughout the community. The Organization and the nation owe him a great debt of gratitude for the services which he rendered.

5. Honours and Awards.

Among officers of the Organization who received honours and awards during the year were the following:—

- Dr. O. H. Frankel, Chief, Division of Plant Industry: Vice-President, Australian Academy of Science.
- Dr. H. R. Marston, Chief, Division of Biochemistry and General Nutrition: Doctor of Science (*ad eundum gradem*), University of Adelaide; and 1958 Mueller Medal, A.N.Z.A.A.S.
- Dr. A. E. Cornish, Chief, Division of Mathematical Statistics: Foundation Fellow, Australian Institute of Agricultural Science.
- Dr. J. G. Davies, Assistant Chief, Division of Plant Industry: Doctor of Science, New England University; and Foundation Fellowship, Australian Institute of Agricultural Science.
- Dr. D. B. Williams, Officer-in-Charge, Agricultural Research Liaison Section: President, Australian Agricultural Economics Society.
- Dr. A. W. Turner, Assistant Chief, Division of Animal Health and Production: Gilruth Award, Australian Veterinary Institute.
- Dr. K. L. Sutherland, Chief, Division of Physical Chemistry: Fellow, Australian Academy of Science.
- Dr. J. H. Piddington, Senior Principal Research Officer, Division of Radiophysics, 1958: David Syme Research Prize, University of Melbourne; and T. K. Sidney (Summertime) Award, Royal Society of New Zealand.
- Mr. H. McL. Gordon, Senior Principal Research Officer, Division of Animal Health and Production: Payne Exhibition, University of Melbourne (in association with Mr. R. F. Riek); and Fellow, Australian Veterinary Association.

- Dr. J. R. Price, Senior Principal Research Officer, Organic Chemistry Section: Fellow, Australian Academy of Science.
- Dr. W. N. Christiansen, Senior Principal Research Officer, Division of Radiophysics: Fellow, Australian Academy of Science.
- Dr. B. Y. Mills, Senior Principal Research Officer, Division of Radiophysics: Fellow, Australian Academy of Science.
- Dr. D. S. Riceman, Senior Principal Research Officer, Division of Biochemistry and General Nutrition: Doctor of Science, University of Adelaide.
- Dr. M. C. Dawbarn, Principal Research Officer, Division of Biochemistry and General Nutrition: Doctor of Science, University of Adelaide.
- Dr. K. H. L. Key, Principal Research Officer, Division of Entomology: Fellow, Australian Academy of Science.
- Mr. I. E. Newnham, Principal Research Officer, Division of Mineral Chemistry: Member of the Order of the British Empire.
- Dr. J. D. Morrison, Principal Research Officer, Division of Chemical Physics: Doctor of Science, University of Glasgow.
- Mr. R. F. Riek, Principal Research Officer, Division of Animal Health and Production: Payne Award, University of Melbourne (in association with Mr. H. McL. Gordon).
- Dr. A. E. Martin, Principal Research Officer, Division of Soils: Doctor of Agricultural Science, University of Queensland.
- Dr. C. K. Coogan, Senior Research Officer, Division of Chemical Physics: Fellow, National Academy of Sciences, U.S.A.
- Dr. A. J. Farnworth, Senior Research Officer, Division of Textile Industry: Member of the Order of the British Empire.
- Dr. W. G. Kauman, Research Officer, Division of Forest Products: Docteur en Sciences, University of Brussels.

6. ORGANIZATIONAL CHANGES.

The Division of Industrial Chemistry has been reorganized to form the Chemical Research Laboratories. Dr. I. W. Wark, Chief of the former Division, has been appointed Director of the Laboratories.

Three Divisions, each with its own Chief, and three independent Sections with Officers-in-charge, have been formed within the Laboratories as follows:—

Division of Chemical Physics—Dr. A. L. G. Rees.
Division of Mineral Chemistry—Mr. R. G. Thomas.
Division of Physical Chemistry—Dr. K. L. Sutherland.
Cement and Ceramics Section—Mr. A. J. Gaskin.
Chemical Engineering Section—Dr. H. R. C. Pratt.
Organic Chemistry Section—Dr. H. H. Hatt.

The Foundry Sands Section continues to be affiliated with the Laboratories.

The Wool Textile Research Laboratories have been renamed the Wool Research Laboratories and the three Units comprising the Laboratories have become Divisions of the Organization. The Biochemistry Unit has become the Division of Protein Chemistry, with Dr. F. G. Lennox as Chief of Division; the Physics and Engineering Unit has become the Division of Textile Physics wth Mr. V. D. Burgmann as Chief of Division; the Geelong Laboratory has become the Division of Textile Industry with Dr. M. Lipson as Chief of Division. Co-ordination of the three Divisions by a research committee will continue.

The Soil Mechanics Section, formerly part of the Division of Soils, has been made an independent Section of the Organization. The Officer-in-charge is Dr. G. D. Aitchison. The Section has recently moved to a new laboratory at Syndal, Victoria.

The decision has been made that the unit of the Division of Plant Industry previously located at the Plant and Soils Laboratory, Brisbane, will be given independent status as the Division of Tropical Pastures. The Chief of the new Division will be Dr. J. Griffiths Davies, former Associate Chief of the Division of Plant Industry and Officer-in-charge of the Plant and Soils Laboratory. The Division will be housed in the new Cunningham Laboratory adjacent to the University of Queensland at St. Lucia, and will continue to work in association with the Division of Plant Industry. These arrangements wlll be effective as from 1st July, 1959.

The former Radio Research Board Laboratory at Camden, New South Wales, has become an independent Section designated the Upper Atmosphere Section, and Dr. D. F. Martyn is Officer-in-charge.

The Editorial Section of the Organization has been made an independent Section with the title Editorial and Publications Section. Dr. N. S. Noble is Editor and Officer-in-charge of the unit.

7. NEW CHIEF, DIVISION OF PHYSICS.

Dr. R. G. Giovanelli, D.Sc., has been appointed Chief of the Division of Physics, National Standards Laboratory, following retirement of Dr. G. H. Briggs, D.Sc., Ph.D.

Dr. Briggs joined the National Standards Laboratory at its inception in 1939 as Officer-in-charge of the Physics Section, which became a Division in 1945.

8. WHEAT RESEARCH UNIT.

Following receipt of a grant from the Wheat Industry Research Fund, the Organization has established a Wheat Research Unit to undertake investigations of wheat quality.

The Unit works in close collaboration with the Bread Research Institute, Sydney. It is located at the Institute's Laboratory and the Director of the Institute, Mr. E. E. Bond, is its Officer-in-charge. Dr. M. V. Tracey has been appointed scientific leader of the Unit.

The report of the Wheat Research Unit appears in Chapter III., Section 22.

9. APPOINTMENT OF OFFICER-IN-CHARGE, WESTERN AUSTRALIAN REGIONAL LABORATORY.

The Western Australian Regional Laboratory houses research staff from a number of C.S.I.R.O. establishments, and serves as an administrative centre for Divisions and Sections undertaking research in Western Australia. Dr. R. C. Rossiter of the Division of Plant Industry has been appointed as Officer-in-charge of the Laboratory.

10. COLLABORATION WITH UNIVERSITIES.

Many C.S.I.R.O. investigations are carried out in co-operation with Australian universities. These studies are described in appropriate sections of this report. The following are new arrangements made with universities during the year.

Since 1951 co-operative research on soil mechanics has been carried out by the Civil Engineering Department of the University of Melbourne and the Organization's Soil Mechanics Section, laboratory space being provided by the University. The University and C.S.I.R.O. have now jointly established a new laboratory at Syndal, Victoria, where these investigations will be continued.

The University of Sydney has given permission for the erection of an aerial system on the university farm, " Mayfarm ", Camden, New South Wales. The aerial is being used in studies of radio propagation by " forward scatter " carried out jointly by the Postmaster-General's Department and the Upper Atmosphere Section of C.S.I.R.O.

Arrangements have been made with the University of Sydney for establishment of a Meat Research and Teaching Centre at the University of Sydney Animal Husbandry Farms, Camden, New South Wales. The Centre, made possible largely by generous private donations, will be used as a teaching establishment and for research into problems of meat production. The Centre includes a Beef Cattle Feeding Unit and the University Meat Laboratory. Dr. M. C. Franklin, William McIlrath Fellow in Animal Husbandry, is the senior C.S.I.R.O. officer at the Centre.

An officer of the Division of Mathematical Statistics has been seconded to the Computation Laboratory of the Applied Mathematics Department, University of Melbourne. The Laboratory, which houses the computor CSIRAC, on loan to the University, serves as a teaching and computing centre for the University and C.S.I.R.O.

C.S.I.R.O. officers have continued to assist universities by giving courses of lectures in their specialist fields, and have also given various single lectures to students in nearly all Australian universities.

The Organization gratefully acknowledges its debt to the universities for help and collaboration in many aspects of its work.

11. Allocation of Land at Monash University.

C.S.I.R.O. is purchasing an area of 38 acres adjacent to the proposed site of the new Monash University in Melbourne. The area will be used to establish laboratories with activities bearing a relationship to the work of the University. The first building planned for the site is a new laboratory for the Division of Chemical Physics.

12. Opening of New Soils Laboratory.

The first building of the new head-quarters for the Division of Soils at Glen Osmond, Adelaide, was officially opened on 13th March by the Speaker of the House of Representatives (the Honorable John McLeay, M.P.).

The Division has since its foundation in 1933 occupied laboratories of the Waite Agricultural Research Institute. The Organization is grateful to the University of Adelaide for making this accommodation so readily available over such an extended period.

The Soil Physics and Soil Microbiology Sections will remain in the Institute's Laboratories, and the Clay Mineralogy Section will continue to be housed in the Mawson Building of the University of Adelaide until the second building of the new Divisional laboratory is erected.

13. Rice Research in Northern Territory.

At the request of the Minister for Territories, C.S.I.R.O. is establishing a Rice Research Station on the coastal plains near Darwin. At this Station studies will be made of nutrition and water requirements of rice and of possibilities for developing varieties well adapted to that environment. Results of investigations should be applicable to areas around Humpty Doo on which attempts to grow rice have been made now for some years. Scientific investigation should reduce the uncertainty and hazard of rice-growing in these areas.

14. Use of Naval Vessels by Division of Fisheries and Oceanography.

The Department of the Navy has made available to C.S.I.R.O. for periods of about twelve weeks a year two frigates specially equipped for oceanographic survey work. These frigates, H.M.A.S. *Gascoyne* and H.M.A.S. *Diamantina*, are fully manned and serviced by the Navy. One will be available for surveys off the east coast of Australia and one for surveys off the west coast.

Investigations at present being conducted into the fisheries resources of Australia are seriously handicapped by the almost complete lack of oceanographical data for the Australian area. The very small craft available to the Division of Fisheries and Oceanography do not permit collection of data necessary for assessing the character of the various water masses and their movements.

Very little information is available on the oceanography of the Australian area. Apart from early expeditions, such as the Challenger Expedition of 1874-75, the only other information of any importance was that obtained by the various expeditions of *Discovery II.* operating in the Southern Ocean south of Australia and New Zealand. These data are completely inadequate for defining current systems and seasonal changes in them which are known to occur.

The assistance of the Navy vessels will facilitate the more comprehensive and regular programme of observations which must be undertaken before a clear picture of the oceanography of the waters surrounding Australia can be developed.

15. Co-operative Industrial Research.

There are various ways in which the Organization co-operates with industry in conducting research. These range from undertaking single sponsored research programmes to co-operation with autonomous industrial research associations. C.S.I.R.O. welcomes proposals for co-operative research programmes from individual firms or industrial groups.

The report of the work of the Industrial Research Liaison Section, established to strengthen liaison between the Organization and secondary industry, is described in Chapter XXXI., Section 4.

The Organization has continued financial support to the Australian Leather Research Association, the Bread Research Institute of Australia, the Wine Research Institute, and the Australian Coal Association (Research) Ltd. Both the Bread Research Institute of Australia and the Australian Coal Association (Research) Ltd. have let contracts for the construction of laboratories on land at North Ryde made available by the Organization. Each of these research associations will be housed in close proximity to related C.S.I.R.O. activities. The new laboratory of the Bread Research Institute will provide accommodation for the C.S.I.R.O. Wheat Research Unit (see Chapter III., Section 22).

A number of new research projects sponsored by industry have been commenced during the year. These include investigation by the Division of Tribophysics of solid lubricating materials derived from Australian beach sand minerals, supported by H. C. Sleigh Ltd.; development of methods by the Division of Mineral Chemistry for determination of the oxygen content of cyanide solutions used in extracting gold from its ores, supported by a group of gold-mining companies within the Chamber of Mines of Western Australia; research in the Division of Physics, National Standards Laboratory, on colourimetric properties of pigmented materials, supported by C.S.R. Chemicals Pty. Ltd.; and study of changes in shell egg quality during marketing, supported by the Egg Producers' Council.

Increased support was received from the group of pulp and paper manufacturing companies who since 1937 have assisted in financing research on chemical and physical problems in paper making in the Division of Forest Products. This annual grant has been doubled. Increased financial support for C.S.I.R.O. research was also given by the Australian Cement and Concrete Association which since 1942 has provided funds for research in the Cement and Ceramics Section, Chemical Research Laboratories. In addition to increasing the grant for this work the Association has also given support for a programme of research on concrete in the Division of Building Research.

A full list of contributions and donations for research received by the Organization is given in Chapter XXXV., Section 2.

16. GRANTS BY ROCKEFELLER FOUNDATION.

The Rockefeller Foundation has, in the past, given generous support to research undertaken by C.S.I.R.O. Two further grants totalling 130,000 dollars have been made by the Foundation. These grants have been made for the purchase of special equipment for the Divisions of Entomology and Plant Industry.

The grant to the Division of Entomology will allow intensification of research on insect physiology and biochemistry. The grant to the Division of Plant Industry will be used for research on genetics and biochemistry of rhizobia, and for investigations on nitrogen and phosphorus deficiencies of Queensland soils.

17. GIANT RADIO TELESCOPE.

The design study for the proposed giant radio telescope for the Division of Radiophysics has been completed. The contract for the constructional work on the telescope which is to be erected at Parkes, New South Wales, has been placed with the firm of Maschinenfabrick Augsburg-Nuernberg A.G. The radio telescope is scheduled for completion early in 1961.

Gifts to C.S.I.R.O. from the Rockefeller Foundation, from the Carnegie Corporation, and from industry and private donors in Australia, together with a matching grant from the Commonwealth Government, have made possible construction of this elaborate scientific equipment.

18. PHYTOTRON.

The Commonwealth Government has made available £500,000 to erect a phytotron at the Division of Plant Industry, Canberra. The phytotron will consist of a series of controlled environment cabinets for research on plant material under a wide range of conditions. The cabinets are being designed jointly by the Engineering Section and the Division of Plant Industry and will be housed in a special building designed and constructed under the supervision of Mr. R. Grounds of the architectural firm of Grounds, Romberg, and Boyd, Melbourne.

19. ADMINISTRATIVE OFFICER CLASSIFICATION.

Following review of administrative activities, the Executive approved introduction of new Divisional Administrative Officer classifications for clerical administrative positions in Divisions and Sections.

It was clear that the Organization's administrative resources had often fallen short of demands imposed by rapidly expanding scientific programmes, with the result that senior research staff had become increasingly involved in clerical administrative activities. Insufficient administrative personnel were available, and this was primarily due to shortage of academically qualified clerical staff, with training in the Organization's administrative practices. Lack of a defined career for such people led to high turnover in Divisional administrative positions, causing further decline in overall performance.

In introducing the new scheme the Executive was concerned to provide an adequate career for those responsible for administrative work in C.S.I.R.O.. It also aimed to ensure that recruitment to Divisional Administrative positions was at a high educational standard, and that subsequent training developed not only proficiency in administrative procedures, but appreciation of research as an activity. It must be regarded as an experimental approach to a problem now widely recognized in discussions on research administration, both in Australia and abroad.

20. OVERSEAS VISITORS.

The number of scientists from overseas visiting C.S.I.R.O. laboratories or collaborating with officers in research showed a marked increase in the current year. The Organization particularly welcomed: Sir Ronald Fisher, F.R.S., University of Cambridge, at present a guest worker with the Division of Methematical Statistics, collaborating with Australian workers in the fields of genetics and statistics; Mr. L. J. F. Brimble, Editor of *Nature,* who visited Australia under the auspices of the Nuffield Foundation and C.S.I.R.O.; Dr. Guy D. Smith, Director, Soil Survey Investigations, United States Department of Agriculture, who visited Australia and New Zealand at the invitation of C.S.I.R.O. and D.S.I.R. to discuss application of an improved system of classification to soils of both countries.

Dr. Paulino Garcia, Chairman of the recently formed Philippines National Science Development Board, accompanied by Dr. Banzon, Chief Scientist of the Board, visited Australia under the auspices of the Colombo Plan to study organization and administration of Australian Government scientific establishments, particularly the C.S.I.R.O.

Dr. A. G. Ashgar, Director of Land Reclamation, Lahore, West Pakistan, visited Australia at the invitation of the Commonwealth Government to examine irrigation and drainage work undertaken in this country. Dr. Ashgar's study arrangements in Australia were made by C.S.I.R.O.

Sir John Cockroft, former Director of the Atomic Research Establishment, Harwell, England, who represented the Royal Society at the opening of the new building of the Australian Academy of Science, Canberra, visited several C.S.I.R.O. Laboratories.

Professor A. W. A. Brown, University of Western Ontario, who visited the South-East Asian and Western Pacific areas at the request of the World Health Organization to advise on insect resistance to insecticides, took part in a seminar on this subject arranged by the Division of Entomology.

Dr. H. Harada, of the Government Forest Experiment Station, Tokyo, Japan, spent six months with the Division of Forest Products studying the structure of wood with electron microscope techniques. Dr. Harada is the first scientist from Japan to work in the Organization as a visiting research worker.

Since 1951, fifteen American scientists visited Australia under Fulbright Awards and carried out co-operative research work with C.S.I.R.O. officers. During the year under review Fulbright Awards were given to the following persons to enable them to work in C.S.I.R.O. laboratories: Professor V. Cheadle, Department of Botany, University of California, to spend nine months with the Division of Forest Products studying fine structure of wood and bark; and Professor V. K. La Mer, Department of Chemistry, Columbia University, New York, to spend six months with the Division of Physical Chemistry.

The Organization has continued to provide facilities for training F.A.O., U.N.E.S.C.O., and Colombo Plan Fellows and students.

21. Overseas Visits.

Officers of the Organization represented Australia at a number of overseas scientific conferences during the year. These included:—

- Interim Meeting of the International Union of Crystallography.
- Third International Conference on Coal Science.
- First International Conference of Coal Petrology.
- F.A.O. Expert Panel on Tick-borne Diseases.
- U.N.E.S.C.O. Symposium on Tropical Vegetation.
- International Conference of the Fracture of Metals.
- United Nations Geneva Conference on the Peaceful Uses of Atomic Energy.
- International Symposium of Radio Astronomy.
- U.N.E.S.C.O. International Advisory Committee on Marine Sciences.
- International Symposium on Fluid Mechanics and the Ionosphere.
- XIth World Poultry Congress.
- International Symposium on Antarctic Meteorology.
- International Congress of Biochemistry.
- International Symposium on Atmospheric Diffusion and Air Pollution.
- Sixth Session of the International Rice Commission.
- Fourth International Conference on Electron Microscopy.
- Meeting of the N.A.T.O. Advisory Group for Aeronautical Research and Development.
- International Committee on Weights and Measures.
- 15th International Congress of Zoology.
- International Biometric Congress.
- International Commission on Illumination.
- Tenth General Assembly of the International Astronomical Union.
- Fourth Carbon Conference.

Dr. S. H. Bastow, Chief Executive Officer, represented Australia at the British Commonwealth Scientific Organization Conference held in Canada.

Mr. Guy B. Gresford, the Research Secretary (Physical Sciences), accompanied the Minister-in-Charge of C.S.I.R.O., the Right Honorable R. G. Casey, on a visit to Japan. The opportunity was taken to establish liaison with research institutions in that country whose work is of interest to Australian scientists.

Six officers went overseas for short periods on F.A.O. assignments, at the invitation of U.N.E.S.C.O., or on Colombo Plan assignments.

Officers of the Wool Research Laboratories visited New Zealand and Japan in connexion with the establishment of the SI-RO-SET wool process in those countries. A number of officers were sent overseas to obtain information on new scientific developments and to acquire specialist knowledge. Officers went abroad for advanced study at the invitation of overseas research organizations.

22. C.S.I.R.O. Post-graduate Studentships.

The Organization continued to award studentships of three kinds to graduates for training in research, both in Australia and overseas. During the year living allowances payable to studentship holders were investigated by the Studentship Committee, which urged that increases be made in awards to maintain parity with other forms of student assistance currently available. The Executive endorsed these proposals. C.S.I.R.O. Post-Graduate Studentships now carry the following living allowances:—

- Junior studentships—£500-£700 per annum.
- Senior studentships—£800-£1,000 per annum.
- Overseas studentships—£750 sterling per annum in United Kingdom and Europe, 2,474 dollars per annum in United States of America.

Junior Post-graduate Studentships are awarded for one year only, to persons holding a pass degree in Science, Agricultural Science, Veterinary Science, Engineering, or Arts with Mathematics as the main subject. During the year 24 of these studentships were awarded, successful candidates (and their universities) being:—

- W. W. Barker (Western Australia).
- A. J. E. Colvill (Adelaide).
- J. M. Eckert (Sydney).
- E. C. Fackerell (Sydney).
- R. C. Fawcett (Adelaide).
- P. S. Ganas (Queensland).
- G. J. G. Greaves (New England).
- J. Greenhills (Tasmania).
- T. P. Hallinan (Sydney).
- C. W. Hassell (Western Australia).
- Miss J. W. Hedger (Adelaide).
- G. A. R. Johnston (Sydney).
- S. Jorna (Western Australia).
- J. P. Kelly (Tasmania).
- D. R. Liljegren (Adelaide).
- P. H. Lucich (Western Australia).
- J. J. Monoghan (Western Australia).
- P. S. Muecke (Adelaide).
- J. Olley (Sydney).
- J. Roberts (New England).
- M. E. B. Smyth (Adelaide).
- R. G. Storer (Adelaide).
- J. R. E. Wells (Adelaide).
- D. G. Wood (New South Wales).

Senior Post-graduate Studentships are awarded for two years initially to persons holding at least an Honours degree in the fields listed. The period of the studentship may be extended for an additional year under special circumstances. During the year 26 awards were made, six of them being subsequently declined. Successful candidates were:—

- C. D. Akon (Sydney).
- J. G. Allpress (Melbourne).
- T. E. Bellas (Western Australia).
- T. Biegler (Sydney).
- Miss J. A. Bosson (Sydney).
- E. W. Deardin (Queensland).
- R. S. Dickson (Adelaide).
- R. B. Donnelly (Sydney).
- D. J. Faulkner (Queensland).
- J. E. Lane (Adelaide).
- J. J. Lowke (Adelaide).
- D. E. Moore (Sydney).
- P. B. Nicholls (Tasmania).
- C. J. Powell (Western Australia).
- R. H. Prager (Sydney).
- D. B. Purser (Western Australia).
- H. C. Robinson (Sydney).
- R. G. Roper (Adelaide).
- D. E. Smiles (Sydney).
- J. R. Wilson (Sydney).

Overseas Studentships are awarded to research workers in science and allied fields who have obtained a Ph.D. or who are about to obtain that degree, to enable them to proceed overseas usually for one year only, to work with leaders of research in their special field of interest. During the year fourteen awards of Overseas Studentships were made, successful applicants being:

- D. A. Adamson (Sydney).
- Mrs. H. Adamson (Sydney).
- G. B. Barlin (Australian National University).
- J. L. Charley (New England).
- N. J. Daly (Western Australia).
- O. T. Denmead (Queensland).
- M. L. Heffernan (Melbourne).
- B. W. Logan (Western Australia).
- J. S. Mainstone (Adelaide).
- E. J. Moore (Western Australia).
- G. M. Philip (Melbourne).
- P. R. Strutt (Melbourne).
- G. W. Taylor (Western Australia).
- D. W. Watts (Western Australia).

In addition, five officers of the Organization have been awarded Divisional Overseas Studentships.

23. SCIENCE AND INDUSTRY ENDOWMENT FUND.

The Executive as Trustees of the Science and Industry Endowment Fund made the following grants to assist research workers:—Dr. Mary E. Gillham, to continue study of ecology of mutton bird nesting areas of Australia; Dr. D. S. Farner, to carry on research on mechanisms controlling reproductive cycles in certain species of Australian birds; Mr. W. Dawbin, to continue investigation on biology and population of whales; Mrs. P. Thomas, to prepare biological B.A.N.Z.A.N.E. reports; Mr. N. V. Dobrotworsky, to continue study of the systematics and ecology of Victorian mosquitoes; Mr. A. W. Parrott, to continue taxonomic studies of Australian parasitic wasps; Dr. J. Pearson, to continue investigations on Australian marsupials; Dr. R. T. Patton, to study distribution and environmental factors of Victorian plant communities; Mr. J. P. Kelsall, to complete study of tammar (*Protemnodon eugenii*) populations of the Abrolhos Islands and Garden Island, Western Australia; Dr. J. A. Keast, Australian Museum, Sydney, to study factors governing vertebrate distribution, speciation, and the annual breeding cycle of birds.

An annual grant for a period of four years was made to the Commissioners of the Exhibition of 1851 Scholarships to supplement scholarships awarded in Australia.

Grants were approved for travelling expenses of the following research workers:—Dr. D. A. Denton of the University of Melbourne to visit overseas research centres investigating adrenal physiology; Dr. J. W. Evans of the Australian Museum, Sydney, to attend the International Entomological Congress in Vienna; Dr. R. W. George of the Perth Museum to examine marine collections at the Australian Museum, Sydney, and the C.S.I.R.O. Laboratory, Cronulla; Dr. G. Mayo, University of Adelaide, to attend a Plant Breeding Workshop, Division of Plant Industry, Canberra. Grants were also made to five students of the University of Adelaide and to a student of the University of Queensland to enable them to attend the School of Marine Biology at the Division of Fisheries and Oceanography, Sydney.

A grant has been approved to assist Professor P. C. Keller, University of London, and Dr. Peter Alexander, Chester Beatty Research Institute, to attend the third Australian Conference on Radiation Biology to be held in 1960.

A grant was made to the Science Teachers' Association of Victoria to provide a bursary for the Association's talent search and to meet the general costs of the search.

24. BUILDINGS AND ACCOMMODATION.

During the year the following buildings were completed:—

New South Wales—
Cobbitty—Beef Cattle Feeding Unit, Division of Animal Health and Production.
Cronulla—Laboratory extension, Division of Fisheries and Oceanography.
Deniliquin—Residence, Division of Plant Industry.
Prospect—Main building, Sheep Biology Laboratory, Division of Animal Health and Production.
Ryde—Workshop building, and carbonization and combustion building, Coal Research Section.

Victoria—
East Melbourne—Additional story, Head Office.
Fishermen's Bend—Slip-house extension, Chemical Research Laboratories.
Geelong—Weaving shed extension, Wool Research Laboratories.
Syndal—Head-quarters and laboratory, Soil Mechanics Section.
Werribee—Laboratory extension, Division of Animal Health and Production.

Australian Capital Territory—
Canberra—Inflammable materials store, Administrative Office, Canberra Laboratories.
Canberra—Workshop, Wildlife Survey Section.

Queensland—
St. Lucia—Cunningham Laboratory, Division of Plant Industry.

South Australia—
Adelaide—Laboratory No. 1, and potting shed, Division of Soils.
Glenthorne—Residence, Division of Biochemistry and General Nutrition.

The following are the more important buildings in course of construction:—

New South Wales—
Armidale—Wing of Rural Science Building, New England University, for Division of Animal Health and Production.
Griffith—Workshop, Irrigation Research Station.
Ryde—New head-quarters and laboratories, Division of Food Preservation and Transport.
Ryde—Inflammable materials store, Coal Research Section.

Australian Capital Territory—
Canberra—Glasshouse insectary, Division of Entomology.
Ginninderra—Residence and implement shed, Division of Plant Industry.

25. FINANCE.

Chapter XXXV. gives details of the expenditure of £8,060,831 incurred during 1958-59 by the Organization from all funds at its disposal. Of this sum £7,538,477 was expended on normal research activities, £385,745 on capital works, and £136,609 on grants to outside bodies. Funds for this expenditure were derived from the Commonwealth Treasury, contributions from other sources including the Wool Research Trust Fund Trust Account, and C.S.I.R.O. revenue from miscellaneous sources.

The following table summarizes the sources of these funds, and activities on which they were expended. Details of expenditure may be ascertained by reference to relevant sections of Chapter XXXV. as indicated in the table.

Source of Funds.	Investigations.	Capital Works.	Grants to Outside Bodies.	Total.
	£	£	£	£
Treasury Appropriation	6,085,301 (Section 1)	75,687 (Section 5)	136,609 (Section 6)	6,297,597
C.S.I.R.O. Revenue	85,505 (Section 4)	..	..	85,505
Total Treasury Funds	6,170,806	75,687	136,609	6,383,102
Wool Research Trust Fund Trust Account	1,058,545 (Section 3)	264,031 (Section 3)	..	1,322,576
Contributions (other than wool) ..	309,126 (Section 2)	46,027 (Section 2)	..	355,153
	7,538,477	385,745	136,609	8,060,831

The Organization is particularly gratified by the way various bodies continue to support it, and by the marked interest shown by certain sections of industry which provided funds for co-operative research. Among the many contributions received, reference may be made to those of the Australian Meat Board, the Australian Dairy Produce Board, the Australian Egg Board, the Queensland Meat Industry Board, the New South Wales Department of Agriculture, the New South Wales Water Conservation and Irrigation Commission, the Metropolitan Meat Industry Board of New South Wales, the Ian McMaster Bequest, the Alexander Fraser Memorial Fund, the Burdekin Bequest, the dried fruits industry, the Australian Institute of Mining and Metallurgy, the State Electricity Commission of Victoria, the Cement and Concrete Association of Australia, the timber industry, the Associated Fibrous Plaster Manufacturers of Australia, the Paint Manufacturers' Association, the United Graziers' Association of Queensland, Broken Hill Associated Smelters Pty. Ltd., the River Murray Commission, the Snowy Mountains Hydro-Electric Authority, the Department of Health, Education, and Welfare (U.S.A.), Smith, Kline, and French Laboratories, U.S.A., Western Australia Chamber of Mines (Inc.), and the Population Council (Inc.), U.S.A.

26. ORGANIZATION.

For carrying out its research work, the Organization has established certain major Laboratories, and a number of Divisions and Sections. The three major Laboratories are the National Standards Laboratory grouping three Divisions, the Chemical Research Laboratories grouping three Divisions and three Sections, and the Wool Research Laboratories grouping three Divisions. There are also fourteen independent Divisions in other research fields which are further subdivided into Sections; and an additional seventeen independent Sections comprising establishments which have not reached a stage of development so far as the scope and magnitude of their operations are concerned to justify their designation as Divisions.

In the present report, an attempt has been made to group the material according to its subject matter rather than according to the Divisions or Sections concerned. Additional chapters and appropriate cross-references have been inserted, however, to permit the work of any particular Division to be reviewed as a whole.

As the Organization's investigations extend on a Commonwealth-wide basis and as many investigations—particularly those concerned with the agricultural and pastoral industries—necessitate experimental work in the field, a number of branch laboratories and field stations have been established in various parts of Australia.

The Head Office of the Organization is in Melbourne and associated with it are the central Library, Agricultural Research Liaison Section, Industrial Research Liaison Section, Editorial and Publications Section, Film Unit, and Publishing and Translation groups. The Organization also maintains Australian Scientific Liaison Offices in London and Washington.

The major Laboratories comprise—

National Standards Laboratory, consisting of the following Divisions:—
- *Metrology*, Sydney;
- *Physics*, Sydney;
- *Electrotechnology*, Sydney.

Chemical Research Laboratories, consisting of the following Divisions:—
- *Chemical Physics*, Melbourne;
- *Mineral Chemistry*, Melbourne;
- *Physical Chemistry*, Melbourne;

and the following Sections:—
- *Cement and Ceramics*, Melbourne;
- *Chemical Engineering*, Melbourne;
- *Organic Chemistry*, Melbourne.

The Laboratories have their head-quarters in Melbourne and branch laboratories in Sydney, Adelaide, and Perth.

Wool Research Laboratories, consisting of the following Divisions:—
- *Protein Chemistry*, Melbourne;
- *Textile Physics*, Ryde, New South Wales;
- *Textile Industry*, Geelong, Victoria.

The independent Divisions are as follows:—

Plant Industry, with head-quarters in Canberra and main laboratories in Canberra and Brisbane, regional laboratories in Perth, Hobart, and Deniliquin, New South Wales, and field stations, experimental farms, &c., at Canberra, at Lawes, Applethorpe, and Mareeba, Queensland, at Trangie, New South Wales, and at Kojonup, Western Australia.

Entomology, with head-quarters and main laboratories in Canberra, a smaller laboratory in Sydney, and field stations at Trangie, New South Wales, at Rockhampton, Queensland, and at Perth.

Animal Health and Production, with head-quarters in Melbourne, laboratories in Melbourne, Sydney, Prospect (New South Wales), and Brisbane, and field stations at Armidale and Badgery's Creek, New South Wales, at Cunnamulla, Amberley, and Rockhampton, Queensland, and at Werribee and Tooradin, Victoria.

Biochemistry and General Nutrition, with head-quarters in Adelaide and field stations at O'Halloran Hill, Robe, and Brecon, South Australia.

Soils, with head-quarters and laboratories in Adelaide, and branch laboratories in Perth, Canberra, Brisbane, Melbourne, and Hobart.

Forest Products, Melbourne.

Food Preservation and Transport, with head-quarters and laboratories in Sydney, branch laboratories in Brisbane and Hobart, and minor laboratories in Gosford, New South Wales.

Fisheries and Oceanography, with head-quarters and main laboratories in Cronulla, New South Wales, laboratories in Perth and Melbourne, and field stations at Hobart and Thursday Island.

Radiophysics, Sydney.
Tribophysics, Melbourne.
Building Research, Melbourne.
Mathematical Statistics, Adelaide.
Meteorological Physics, Melbourne.

Land Research and Regional Survey, with head-quarters in Canberra, and field stations at Alice Springs and Katherine, Northern Territory, and in the Kimberley region, Western Australia.

The following are the independent Sections:—

Irrigation Research Stations, at Merbein, Victoria (Murray Irrigation Areas), and Griffith, New South Wales (Murrumbidgee Irrigation Areas).

Fodder Conservation, Melbourne.

Ore-dressing Investigations, Melbourne, and Kalgoorlie, Western Australia.

Mineragraphic Investigations, Melbourne.
Dairy Research, Melbourne.
Coal Research, Sydney.
Physical Metallurgy, Melbourne.
Wildlife Survey, with head-quarters in Canberra and field stations at Perth, and Albury, New South Wales.
Mathematical Instruments, Sydney.
Animal Genetics, Sydney.
Agricultural Research Liaison, Melbourne.
Engineering, Melbourne.
Industrial Research Liaison, Melbourne.
Soil Mechanics, Melbourne.
Upper Atmosphere, Camden, New South Wales.
Wheat Research Unit, Sydney.
Editorial and Publications, Melbourne.

In addition, regional centres (co-operative research units staffed with officers from the appropriate specialist Divisions to attack the problems of a particular region) have been established as follows:—

Tasmanian Regional Laboratory, Hobart.

Western Australian Regional Laboratory, Perth.

II. SOILS.

1. General.

Understanding of soil fertility is essential for efficient land use. Fertility is the resultant of complex chemical, physical, and biological soil conditions and processes. Research must be undertaken on the characteristics and distribution of Australian soils to develop fully the resources of the agricultural, pastoral, and silvicultural industries. Research is also necessary on mechanical aspects of soil behaviour important in civil engineering.

The Organization's main centre for research on soils is the Division of Soils with head-quarters in Adelaide, and the work of this Division is described in Sections 2-7 of this Chapter.

Research on the engineering aspects of soils is undertaken at the Soil Mechanics Section, at Syndal, Victoria (see Section 8 of this Chapter).

Work on soils with special reference to their behaviour under irrigation is undertaken at the Commonwealth Research Station (Murray Irrigation Areas), Merbein, Victoria, and at the Irrigation Research Station (Murrumbidgee Irrigation Areas), Griffith, New South Wales (see Chapter IV., Sections 2 and 3), and at the Regional Pastoral Laboratory, Deniliquin, New South Wales (see Chapter III., Section 18).

Division of Soils.—The Division's first head-quarters laboratory, standing on a site made available by the University of Adelaide, was completed in August, 1958, and officially opened in March, 1959. A second laboratory, on the same area, which will complete the housing of all head-quarters staff, is now designed.

The Division's regional groups have been given more autonomy in administration and the selection of projects in research programmes. The Officer-in-Charge at each main centre—Brisbane, Canberra, Perth, and Hobart—thereby becomes the leader and coordinator of scientific soils work undertaken by the Division in his region.

Four research staff spent the year working on special grants at American universities. A one-year exchange of a pedologist with the New Zealand D.S.I.R. Soils Bureau has proved satisfactory as the first of a proposed series of such working exchanges of soil scientists between the organizations.

Soil Mechanics Section.—The Section's new Laboratory at Syndal, Victoria, was completed during the year and staff are now in occupation. A branch of the Section operates in Adelaide, and close scientific relationships are maintained with the Division of Soils.

The Section's programme embraces all aspects of soil behaviour of engineering significance and is directed to two principal fields of civil engineering research: (*a*) Building research, in which the two major practical projects are shallow foundations for domestic type structures in urban and rural areas, and deep foundations for major structures; (*b*) road research, with special attention to movements in pavement subgrades, soil stabilization, and field evaluation of stabilized pavement components.

The Section operates in close collaboration with the Civil Engineering Department, University of Melbourne, both establishments sharing joint facilities and participating in lecture and post-graduate research programmes. Liaison with other universities is increasing.

2. Soil Survey and Pedology.

(Division of Soils.)

A study has been completed of the soils of the Swan Coastal Plain in Western Australia where for the first time in Australia a complete chronology and geomorphic history of all the soils of an area has been established and this information related to factors which govern soil fertility.

Of practical significance in arid regions of Australia has been the measurement of water consumption throughout a 12-month cycle of a crop of lucerne at Alice Springs. These data are important in the planned use of limited underground water supplies of suitable quality found in small aquifers such as that of the Todd River Basin at Alice Springs.

A manuscript map of the soils of South Australia was prepared for discussion at the A.N.Z.A.A.S. Conference in Adelaide in August, 1958, and it has been decided to prepare an atlas of Australian soils using the geographical (1 in 10^6) sheets as a base for mapping the soils. The work is expected to occupy a coordinating officer five years.

(*a*) *Western Australia*.—Further research into the principles governing distribution of soils at Merredin made possible definition of four paired erosional-depositional systems affecting the chemistry, morphology, and land-use characteristics of these soils. Each surface has typical relief, vegetation, drainage, and soils, and in general major soils of each surface differ from those of other surfaces. A power-driven core sampler, which will take undisturbed samples to 30 feet, will be used for a more intensive investigation of depositional systems of the valley sides and floors. The study will provide pedological data and information for an understanding of the hydrology of the wheat-belt valleys, where rising saline water-tables are a longstanding problem. Using information from geomorphic studies, it has already been possible to specify and recognize soil associations with considerable accuracy, and units so defined have been used to map a total of 1,000 square miles in the Merredin area.

The work at York has now been concluded. The distribution pattern of the soils is controlled by post-Tertiary erosional history. While older surfaces are lateritic, they have been considerably modified, resulting in the formation of extensive deposits of yellow sandy material. It is proposed that a great deal of the sand plains of Western Australia originated in this way. The geomorphic units have been used to define soil associations now mapped over 800 square miles.

(*b*) *South Australia*.—In the south-east soil reconnaissance continued of counties Robe and Macdonnell, an area of some 3,700 square miles. Mapping of soil associations and collection of samples should be completed in another two months. The soil map of this area will join with that of County Grey, for which a report has now been completed, thus giving a complete cover for the Lower South-east region.

The investigations made in the Elizabeth township area, north of Adelaide, have concluded and reports on the soils have been compiled in connexion with design of house foundations.

A report has been issued dealing with the distribution of soils around Lake Alexandrina and Albert, others in the course of publication deal with part of the Barossa district, the Tatiara district, and County Grey.

(c) *Alice Springs Subregion*.—Reconnaissance mapping continued of the Rodinga and Alice Springs military sheets (4 miles to the inch). Both sheets of 6,000 square miles each have been completed and reports are in preparation.

(i) *Reconnaissance Mapping.*—About half the area involved is occupied by the Simpson Desert or rocky and mountainous country associated with the MacDonnell and Harts Range systems. Such areas have been omitted from all but a marginal examination. The remainder of the area consists of alluvial plains, sand sheets partly wind-sculptured, and undulating country.

A start was made on reconnaissance mapping of the adjacent Hermannsburg sheet.

(ii) *Detailed Soil Surveys.*—In response to requests made by the Lands Branch of the Northern Territory Administration an area on the east side of Alice Springs township was examined in detail. The area was a suggested site for Government housing. A large portion had highly saline soils, and further areas had in addition soils containing hard pans which would affect their reclamation for gardening and beautification. In view of the report plans for the settlement of the area were abandoned.

For planning development of Alice Springs the town district was surveyed in detail. This survey encompassed all land within a 2-mile radius of the post office and indicated areas suitable for housing.

Observations on use of water by lucerne commenced in September, 1957, and were completed in August, 1958. Lucerne requires approximately 0.1 inch of water per day in winter and 0.4 inch a day in the summer. By establishing a correlation between water use and a climatic factor such as evaporation (for which mean monthly values are available) the normal daily water requirements can be stated for each month of the year. Each acre of lucerne in central Australia appears to require, for maximum yield, something over 2,000,000 gallons of water each year.

An officer from this region accompanied an expedition from Leigh Creek in South Australia up the Strezlecki Creek to Innamincka and Birdsville in Queensland. Soils from this little-known region were described and sampled for laboratory examination.

(*d*) *South-eastern Region.*—Edaphic investigation of soils has been initiated at several centres. An officer has been located at Griffith to determine the soil characteristics limiting irrigated pasture growth in that area.

A new centre for soil work has been established at Armidale and the Division's officer stationed there is working in collaboration with C.S.I.R.O. agronomists. Edaphic work will be undertaken at this centre also.

A reconnaissance map and report on the Canberra City area were prepared at the request of the National Capital Development Commission. Field work continued on the Southern Tablelands regional research and extension study, New South Wales, in the form of further studies in the Yass Valley, and a preliminary report on the soils and landscape was prepared for the Committee in collaboration with the Agricultural Research Liaison Section. Field demonstrations were also arranged for this project.

Soil surveys of the Sydney University properties at Badgery's Creek and Cobbity have been made to facilitate agronomic investigations in these areas. Preliminary reconnaissances were made on the north coast of New South Wales to initiate a programme of soil investigations there, particularly in the Kempsey area.

(*e*) *Queensland.*—Current emphasis in the field programme is on land use, with increasing interest in the relationship of soil patterns to major geomorphic surfaces, depositional systems, and to their origins and relative ages.

Following completion of the reconnaissance survey of the Brisbane-Beenleigh area a more detailed study was made of soils derived from the Logan River alluvium and their relationship to the river terraces, including a survey of 2,500 acres in the Sunnybank-Runcorn area. The low inherent fertility of the Brisbane-Beenleigh soils was confirmed by laboratory data for type profiles. Of special interest is the low phosphorus status of the soils derived from basalt. Most of the podzolic and red earth soils have low to very low content of the major nutrients phosphorus, calcium, and potassium. These studies have now been concluded.

Reconnaissance survey of soils and main vegetation types of Queensland brigalow lands has progressed rapidly and is nearing completion. Mapping has been based on air-photo interpretation supported by road traverses permitting examination of all major occurrences of brigalow. Four main groups of clay soils differing in depth, parent material groups, reaction profiles, degree of gilgai development, and liability to seasonal flooding have been delineated. Surface samples and representative profiles are being analysed for major plant nutrients, salt content, and soil reaction as an assessment of soil fertility.

Information on the main vegetation types is of special interest in relation to land clearing problems and systematic observations suggest a relationship between brigalow regrowth problem and particular soils. In co-operation with the Division of Plant Industry a brief survey was also made of the *Harrisia* cactus problem of northern areas where the densest infestation occurs in brigalow forests.

The regional soil survey of south-east Queensland was extended into the Central Burnett district with mapping of a 500 square mile area surrounding Gayndah. About half of this area consists of elevated, steep, and stony land under forests. Black earths and associated dark clay soils are a major component of the soil pattern of the lower gently sloping lands which also include large areas of solodized solonetz and solodic soils and a range of podzolic types. Apart from limited areas of alluvial soils along the Burnett River, intensive farming is mainly associated with friable red clay soils, of various ages and degrees of development, derived from basalt rocks.

Soil layering associated with cyclic landscape development is evident in parts of the area. The reconnaissance soil survey will be extended to cover at least 2,000 square miles of the Central Burnett region.

(*f*) *Tasmanian Region.*—The regional survey was continued. One sheet of 450 square miles was printed this year, bringing the total area of the " reconnaissance soil map " to 3,340 squares miles. Maps of two other rectangles each of 450 square miles are almost complete. The Oatlands sheet is a good section of pastoral Midlands country at moderate elevation, and is particularly suited to study of soils formed on various sandstones of the Triassic System in an area of fairly low rainfall and low winter temperatures. Work in the Oatlands rectangle was done by an officer of the Soil Bureau of the New Zealand Department of Scientific and Industrial Research, stationed for ten months in Tasmania on an exchange basis. An officer of the Division has been working in the South Island of New Zealand for a similar period.

3. SOIL CHEMISTRY.

(Division of Soils.)

(*a*) *Head-quarters, Adelaide.* — (i) *Atmospheric Chemistry.*—Collection and analysis of air samples from Alice Springs and south of Adelaide continued until the end of the International Geophysical Year in December, 1958. Examination of rainwater samples from forest reserves at Mount Burr and Mount Crawford were completed and results summarized. Work continues on rainwater samples from Alice Springs and Katherine (Northern Territory) and from Merbein (Victoria).

(ii) *Pedological Investigations.*—The genetic sequence of soils—solonchak, solonetz, solod—is being studied with emphasis on their salinity characteristics. Three sites were elected for study on a solodized solonetz in the Mount Crawford Forest Reserve, and pH and salinity are being determined at regular monthly intervals. Two characteristic structural columns were carefully removed from the B horizon of this solodized solonetz and dissected for measurement of various chemical and physical properties in relation to position within the structure.

(iii) *Potassium Studies.*—The pot experiment on exhaustive cropping of five samples of a Tasmanian soil (Frodsley sandy loam) of varying potassium status has been completed. First signs of potassium deficiency did not appear until the second crop and then only in the soil of lowest initial potassium status. The third and fourth crops showed marked potassium deficiency and significant responses to applied potassium for all five soils. Severity of the deficiency was related to initial level of exchangeable potassium. Potassium content of herbage of the control pots fell to very low levels.

Potassium absorbed from the control pots during the whole experiment was generally slightly in excess of that originally present in the soil as exchangeable potassium. The additional amounts so released from other sources were quite small.

For comparison with these soils a contrasting soil containing illite, Urrbrae sandy loam, was examined in parallel pot and laboratory experiments. In this case the fourth crop was still high in potassium and yields were not significantly reduced. Comparison of total amounts of potassium taken up from this soil by the four crops with decrease in exchangeable potassium, disclosed that comparatively large amounts of this element had been derived from sources other than the exchangeable fraction. Here again treatment of the soil with various extractants of increasing strength confirmed the capacity of this soil to maintain higher levels of exchangeable potassium by release from clay minerals.

Ability of illitic clay minerals generally to supply potassium to plants and to the soil solution is under investigation in co-operation with the Clay Mineralogy Section. Six soils, containing illite in various degrees of degradation, are being examined in pot and laboratory experiments. The work will be extended later to a wider range of soils.

(iv) *Phosphate Studies.*—The long-term field experiment to measure residual value of superphosphate applied with earlier crops has been continued. The soil being examined is one with accumulated residues from 23 cwt. of superphosphate, applied during earlier cropping. At the start of the field experiment no response was obtained from currently applied superphosphate but phosphate status of control plots has now been depleted to the point that the last two crops have shown marked responses. Changes in soil phosphate levels are being studied by chemical extractants. Preliminary pot experiments indicate that subterranean clover can make greater use of residual superphosphate than wheat.

Other work on availability of phosphates in soils involved a study of the chemistry of aluminium. Examination commenced of the solubilities of aluminium hydroxides at various pH values.

(v) *Nutrition of Pines.*—In a pot experiment now in progress for one year addition of superphosphate to *Pinus radiata,* growing on lateritic ridge soil from Second Valley, South Australia, showed early responses due to placement. These early responses disappeared as the trees grew older. This soil is extreme in phosphorus deficiency. Application of sufficient phosphate gave reasonable tree growth whereas in its absence this was almost nil. In spite of early growth being less vigorous later responses from Rhenania phosphate were equal to those from superphosphate.

Needle analyses of healthy and poor trees failed to indicate other obvious deficiencies. Competition studies showed that in the early stages of forest growth surrounding native vegetation immobilized about ten times the amounts of nitrogen, phosphorous, and potassium taken up by the pine trees.

(vi) *Trace Element Studies.*—Cobalt, copper, manganese, molybdenum, and zinc status of 28 soil profiles from Queensland have been determined by spectrochemical techniques. Samples taken at sites widely scattered over the eastern part of the State included members of the following soil groups: grey and brown soils of heavy texture, black earths, krasnozems, red earths, red brown earths, solodized solonetz, lateritic podzolic, red podzolic, terra rossa, and rendzina. Total content of these trace elements was at a satisfactory level for most of the soils. Exceptions were a low content of all elements except molybdenum in lateritic podzolic soils, of cobalt in some red earths, and of all five elements in some solodized solonetzic soils.

Distribution of the trace elements was studied in soil profiles of each group. This showed that it should often be possible to obtain a useful estimate of the trace element status of a complete profile from analysis of the surface sample.

In addition to profile samples, 90 surface samples from Queensland were analysed for the same five elements.

Results for profile samples from Queensland, together with those for profiles of krasnozems, black earths, brown earths, and grey-brown podzolic soils from Tasmania, were used in an examination of the relation between soil trace element content and that of the parent material of the soil. In many cases there was no measurable relation.

(vii) *Other Spectrographic Investigations.*—It has often been claimed, but without evidence based on a comparison of the two methods, that cathodic excitation is much less subject to the harmful effects of self-absorption of the analysis line than anodic excitation. The claim has been verified and it has also been shown that self-absorption can be reduced to a negligible level by dilution of the sample with graphite powder or potassium sulphate in those few instances in which it is serious in the anodic excitation of soils and plant ash.

Following an overseas report of a serious interference by calcium lines with the conventional analysis lines for vanadium, tests were made to determine the importance of this interference in analytical work done in this laboratory. It was found that the usual analysis line for vanadium may be used for samples with less than 11 per cent. of calcium.

(viii) *Miscellaneous.*—Work continued on collection and compilation of quantative physical and chemical data to supplement descriptions of the Great Soil Groups given in the " Manual of Australian Soils ".

The indicator method for measurement of soil pH in the field has been re-examined and improved. A new mixture of three indicators gives a series of bright colours over the range pH 2-10.

Flame photometry for the determination of lithium and calcium in soil extracts is being further investigated. The technique offers the most satisfactory method for the determination of lithium. It can be used as a very rapid method for calcium in many cases, provided there is recognition of the interferences possible in the presence of other elements. By fitting an infra-red sensitive photocell to a standard flame photometer the sensitivity of the method for potassium has been greatly increased. This is proving of value in direct analysis of very dilute solutions of potassium obtained in the course of solubility studies with illites.

Improved indicators and indicator mixtures for ethylenediaminetetraacetic acid (EDTA) titrations have been examined. Direct titrations can now be made of calcium and magnesium in alcoholic ammonium chloride extracts of carbonate soils.

(*b*) *Queensland Region—Brisbane*.—Scattered results from other laboratories have shown that mineral constituents are released from soils during extraction of organic matter. Work in the Division has shown that these constituents are not effectively removed by conventional alkali dispersion and acid precipitation of organic matter. Treatment with ion exchange resins in the hydrogen form removes most of the associated metals such as iron and aluminium but one major ash constituent (silica) is not appreciably reduced. Silica is released in very large amounts during alkali extraction of some soils. The amount extracted from the surface horizon of a black earth exceeded the amount of organic carbon in the extract. Mineral matter could also play an important role in stabilizing humus against further decomposition. More evidence will be sought of the effect of mineral constituents on the properties of soil organic matter. Podzol B horizons generally may provide a relatively simple starting material for studies of soil organic matter.

Further investigations were made on acid montmorillonitic clay subsoils of the brigalow area. These soil horizons apparently contain free silica in a reactive form. Soil extracts made under both acid and alkaline conditions contain more silica than alumina and contrast with some other clay soils of low pH.

A systematic survey of the chemical fertility of important soil groups in south-east Queensland is in progress, using both chemical and pot experimental techniques. For the latter, *Phaseolus lathyroides* has been employed as the test crop, and the response to nutrients evaluated using a subtractive method. Several soils from the brigalow zone and some basaltic krasnozems have so far been examined and all show responses to phosphate. One brigalow surface soil from Tara, with a pH of 7.3, also gave a response to molybdenum.

Study commenced in 1958 of the effects of several years' growth of a tropical legume (*Desmodium uncinatum*) on the chemical properties of a lateritic podzolic soil in the coastal " wallum " country. Some measure of the build-up of soil organic matter was sought. Preliminary results have indicated substantial increases in total nitrogen and phosphorus under plants receiving phosphatic fertilizer compared with the controls with no added phosphate. These studies are continuing, and an attempt will be made to determine depth of penetration of carbon, nitrogen, and phosphorus in this soil.

The establishment of tropical legumes on soils of moderate to low phosphate status is of importance in Queensland, and interest attaches to various techniques for study of soil phosphate availability. Studies commenced to compare Schofield's phosphate potential (measured in dilute calcium chloride solution) with more conventional methods of assessing phosphate status. Studies are now being made of the kinetics of ^{32}P exchange with soil phosphate and its relation to phosphate potential. Determinations of isotopically exchangeable phosphate, and of Larsen values using different crops in pots, are also under way using ^{32}P.

In a co-operative project on the formulation of nitrogen balance sheets in soil/plant relationships, a micro-Dumas apparatus for determination of total nitrogen in soils has been employed. Early results show much higher values using this method than were obtained from conventional Kjeldahl determinations.

Routine analysis of soil samples collected by the Soil Survey and Pedology Section continued. The largest groups of profile samples analysed during the year have been collected from the Mareeba Tobacco Research Institute, the Beenleigh area, and the brigalow country. A large number of surface samples from the brigalow belt is being examined to assess variability in fertility of these soils.

(*c*) *Tasmanian Region—Hobart*.—In a study of cobalt status eighteen soils, half of them basaltic krasnozems from the Burnie-Table Cape area and the remainder representing groups from northern Tasmania, are under test with subterranean clover as the main test plant. Total cobalt content of basaltic krasnozems of the north-west coast, while generally moderate to high, varies widely even within the one soil series. Within the one soil series and within a restricted area there are localities where animals show cobalt deficiency and others where they do not. These aspects are being investigated and correlations sought. Most areas of known cobalt deficiency in this State are in districts of improved pastures with relatively high stocking rates. Under these conditions application of cobalt to the soil with fertilizer is generally believed more economical than the alternative use of cobalt " bullets ". Knowledge of behaviour of cobalt in such soils is therefore required. The Tasmanian Department of Agriculture is studying cobalt nutrition of animals and wherever possible the two lines of investigation are being co-ordinated. A systematic study of the cobalt status of each group of soils defined and mapped in the reconnaissance soil survey is also being attempted.

General laboratory examination of soil samples from surveys continued and analytical data for soils of the Burnie-Table Cape area have been completed and collated.

(*d*) *Western Australian Region—Perth*.—Chemical examination of soil profiles from Quairading, Merredin, and Newdegate and about 30 analyses from parent materials and various horizons of deep profiles in the York area have been completed. Routine determinations have been carried out on samples submitted by the Division of Land Research and Regional Survey from the Wiluna-Meekatharra area. Loss of phosphorus from the surface of 6 inches of two coastal plain soils, one with a sandy surface and the other loam with clay at 1-2 inch, has been investigated. Leaching from the surface horizon has been demonstrated for the sand and loss through erosion appears likely for the fine-textured soil.

Analytical data have been collected from records of the Government Chemical Laboratories in the study of the growth of pines in Western Australia. These results are being studied critically before planning further work in collaboration with the Forests Department of Western Australia.

4. Soil Physics.

(Division of Soils.)

(*a*) *Head-quarters — Adelaide*. — (i) *Hydrology of South-eastern District, South Australia*.—Investigation, undertaken jointly with the South Australian Department of Mines, of the hydrology of shallow ground-water in County Cardwell, Upper South-East, has concluded. Native mallee heath vegetation uses for transpiration all local rainfall during normal years, which penetrates on the average about 10 feet below the soil surface. It is unlikely that a change in vegetation such as establishment of perennial pasture species (lucerne and phalaris) will alter the local rainfall-soil moisture regime.

Ground-water, typically lying at a depth of about 30 feet below ground surface, must be recharged by foreign water, presumably coming from the east and south-east by overland flow and underground, in wet winters, when low-lying areas such as Alf's Flat are inundated. The ground-water has a slope of about 1 : 5,000 and discharges to the Coorong and the sea.

An estimate of the time scale of water flow, particularly of the passage of a pulse of water through the aquifer, shows an order of magnitude of hundreds of years.

This investigation on the hydrology of portion of the Upper South-East of South Australia being complete, planning has commenced of a new project to investigate the evaporation and ground-water regime of the South-eastern district generally.

(ii) *Soil Moisture Regime under Pine Forest.*—Seasonal soil water conditions are being investigated under three sites on the Second Valley, South Australian State Pine Forest. Results point to an undesirable shallow water-table on the laterite soils of ridges and tablelands, with improving soil drainage conditions on slopes of hills.

(iii) *Estimation of Soil Water by Neutron Scattering.*—Calibration of the device has been investigated for the effect of absorption of slow neutrons by solid components of the soil. Changes in boron content from 2 to 100 p.p.m. affect the slope of the calibration curve by about 10 per cent. The same change in slope would be caused by a change in chlorine content of 0.0074 g/g. Calibration depends enough upon soil solid components to warrant individual calibration for each soil, for greatest obtainable accuracy.

The soil water content profile is smoothed by the neutron scattering probe because the sample size (about 20 cm. radius) tends to average water content at any one point. A method has been developed for computing the deviation of measured water content from " true " water content.

(iv) *Measurement of Water Content of Brown Coal.*—In co-operation with the Isotopes Section of Australian Atomic Energy Commission Research Establishment, the feasibility was investigated of measuring by radioactive methods, the water content of brown coal at the briquette factory of the State Electricity Commission, Yallourn, Victoria. The neutron scattering method was used to measure the volume water content, and a gamma ray transmission method was used to measure coal density simultaneously. Results were inconclusive and further work must be undertaken to assess the practicability of the method.

(v) *Permeability of Soils to Water.*—Measurement of distribution of water content in soil columns for determination of unsaturated permeabilities, using a beam of gamma rays, proved successful. Techniques are now sufficiently developed to investigate water movement through soil under a range of conditions of soil structure, temperature, and evaporation.

(vi) *Diffusion of Gases through Porous Material.*—An equation for diffusion of gases through porous materials has been developed on the basis that the chance of one pore communicating effectively with another increases with porosity. This is a departure from equations currently in use employing the Kozeny-Carman tortuosity factor.

(vii) *Soil Tillage.—Strength of agricultural soil:* This and the two following projects are directed primarily towards tillage problems. In a study of the effect of water content on resistance of loose soil to shear and compression forces, it was found that in saturated soil of weak structure, its impermeable nature at relatively low loads resisted compaction to an ultimate density for the applied load. In soils with strong structure the strength of the aggregates resisted crushing and determined the strength of the soil bed and the ultimate density under a load.

An unsaturated bed of soil compresses to an ultimate density but the strength is greater. This increase in strength has been explained on the basis of the suction that develops in the bore water as the soil is strained.

Role of cultivated layer in controlling soil water measurement: Wind tunnel tests have shown that the size of the clods in soils packed in the laboratory affects the rate of water loss to the air. Where pores between clods are greater than 2-3 mm. in diameter rate of loss increases beyond that accounted for by liquid flow or by molecular diffusion in the vapour phase. Work in other fields dealing with heat transfer has shown that convection becomes important above this pore size. Experiments to elucidate the process in soils were inconclusive. Importance of the convection factor under field conditions will be studied on a site near Adelaide.

Control of soil fertility by tillage: Published work has been reviewed on the influence of soil structure on the organic matter cycle in soil. Through its effect on soil, climate, and development of inaccessible sites structure might play a dominant role in determining loss or accumulation of soil humus.

Investigations on changes in soil carbon content have been hampered by the lack of a suitable method for the continuous measurement of the carbon dioxide output from the soil. An infra-red gas analyser has been installed for use on this work.

(viii) *Stabilization of Soil Structure with Polymers.*—Soil crumbs consist principally of clay crystals and quartz particles and a study is being made of how these are held together. Clay crystals are aggregated into subparallel regions termed domains. On the latest laboratory results, it has been proposed that natural polymers from soil organic matter, and synthetic soil conditions, link the external surfaces of the clay domains to quartz particles.

(ix) *Swelling of Clays.*—The swelling pattern of clay is of much interest not only as such, but also because stabilizing treatment will reduce the swelling. Swelling of orientated flakes of pure calcium saturated clays has been measured optically. The free energy of water in clay at which swelling changes from crystalline to Gouy-Stern double layers has been determined. This transition appears to correspond to the boundary between " residual " and " normal " swelling. Energy barriers to swelling have been found for calcium clays at small separations of the clay crystals. The hygroscopic coefficient, one of the oldest empirical measurements in soil physics, has been given a theoretical basis using these results.

(x) *Sealing of Earth Dams.*—Investigation into seepage from earth dams has continued in conjunction with the Department of Agriculture. The laboratory technique for measuring permeability of soil (after varying degrees of compaction) has been improved. With the improved apparatus, samples from nine leaking dams and seventeen proposed dam sites have been tested. Of the nine, three leaked owing to faulty construction, three owing to structural stability of the soil, and three because of gravel seams. Tests indicated that seepage could be prevented from the last two categories by addition of sodium tripolyphosphate or bentonite, respectively. Two dams, one from each of these categories, have been treated with entirely satisfactory results. Of the seventeen proposed sites, ten would seal naturally, five would require tripolyphosphate, and two, in which the soil contained more than 20 per cent. lime, would require addition of carboxmethyl cellulose. Simpler field tests have been developed for diagnosing the treatment required for sealing any particular site.

Leakage through wall blowholes in a dam when first filled after drying out in summer has been found due to dispersion of the clay, and may be prevented by mixing salt into the dam walls.

(*b*) *Queensland Region — Brisbane.* — (i) *Structure Alteration in Cultivated Soils.*—Favourable conditions during the 1958 season resulted in a good wheat crop on experimental plots on Mywybilla clay. There was a slightly increased yield with deep working, with wheat yields at 23.8, 24.9, and 27.5 bushels per acre corresponding respectively with cultivation to 3, 7, and 12 in. during the fallow period. The excellent germination obtained compared to previous experience possibly results from more intensive preparation of trial plots. In this respect germination is related more to management than to specific soil properties. Improvement in yield may be due to a slightly improved fertility in the deep worked plots where the shattering of massive aggregates presents new soil surfaces for root exploitation. Soil water appears to have a dominant effect, and on a contiguous area with normal cultivation following long fallow, yields of 36 bushels per acre were obtained.

Further information has been obtained on the different rate of water evaporation from deep worked plots. The greater water loss is a response to higher porosity induced by cultivation and may prove the limiting factor in use of deep cultivation on these soils. Pot studies are proposed to study influence of cracking in water loss and effect of rolling to reduce evaporation from surface mulch.

(ii) *Water Content Changes in Natural Soils.*—Field observations on the joint project with the Ecology Section, Division of Plant Industry, in the Whian Whian Forest, New South Wales, were terminated in October, 1958, but stream flow recordings were continued until May, 1959, to obtain further information on discharge during the wet season. Analysis of the observations is in progress.

Further infiltration measurements were made to investigate disturbance associated with normal logging operations within the watershed. As possible sites for initiation of erosion and siltation in reservoirs, these areas could be more significant and care is necessary in siting with respect to topography.

(iii) *Effect of Vegetation Height on Water Use by Pastures.*—Complementary measurements of soil moisture fluctuations under swards of different species of *Paspalum* have been commenced. The species selected differ in morphology from prostrate to tall tufted types and different cutting frequencies are superimposed. Despite differences in height, water loss per unit area of exposed surface appears much the same. Following cutting there is decrease in water use associated with loss of leaf surface and vitality of pasture.

(iv) *Miscellaneous.*—Small projects have been carried out in response to requests. Suction curves of red earth soils have been studied to define soil moisture release and assist field experimentation at the Tobacco Research Institute, Mareeba. Porosity relationships have been measured for aggregates from layers of assumed different age in soils of the Gayndah area.

Gypsum blocks and associated equipment have been installed at Goodnight Scrub, near Maryborough, for the Queensland Forestry Department, and experimental plots laid out to study germination and survival of hoop pine (*Araucaria cunninghamii*). A method of determining equilibrium water contents in pot trials was developed and appears successful. One advantage of standardization of physical condition of soil in pots, and better water control, has been a reduction in the coefficient of variation over the trial.

(*c*) *South-eastern Region — Canberra.* — The Soils Physics group has not yet received all its experimental equipment, most of which has been specially designed and is still being constructed in C.S.I.R.O. workshops.

Bulk density, porosity, and particle size distributions have been determined on samples from the Murrakool area. This has thrown light on the progressive change of soil materials with aging. Macroporosity decreases as clay content increases, but rate of decrease in macroporosity is greater in older soils. In some soils of intermediate age increase in macroporosity with increasing clay content indicates that secondary voids (cracks between soil aggregates) have developed at this stage. The effect is lost in older soils. These changes may be important in drainage problems; field observations suggest a relationship exists between drainage condition and age of soil. Detailed particle-size studies led to understanding of dune-sands and parna, and their relation to eroding soils. Routine particle-size analyses of soils from several areas in New South Wales have also been carried out.

5. SOIL MICROBIOLOGY.

(Division of Soils.)

In this section microbiological and biochemical techniques are used to study soil fertility and pedogenesis. Fertility investigations include interactions between rhizobia and legumes, between mycorrhiza and pines, between rhizospheres organisms and their host plants, decomposition of organic matter and minerals, and release of plant nutrients by microorganisms. As a contribution to pedogenesis the chemical nature of humus from various soil types is being compared.

(*a*) Rhizobium — *Legume Studies.* — (i) *Pea-Vetch Cross-inoculation Group.*—Further cross-inoculation tests between more than 100 strains of the *Rhizobium leguminosarum* group and nine host legumes confirm that this group is very heterogeneous in ability to form effective nodules. One hundred and fifty strains were screened using 45 biochemical reactions. Two other representatives of the family Rhizobiaceae, viz. *Chromobacterium violaceum* and *Agrobacterium radiobacter*, were included in the tests. Again there was considerable diversity of reaction, but patterns recurred frequently enough to raise hopes of classifying some of these rhizobia.

(ii) *Role of Calcium in Nodulation.*—Green-house experiments continued on the role of calcium in promoting nodulation of subterraneum clover and lucerne in acid soils. (Mt. Compass sand, pH 5.2.) Addition of bicarbonates has a deleterious effect upon the host legumes rather than upon their rhizobia. This is antagonized by addition of calcium salts, suggesting that one function of calcium is to reduce the level of bicarbonate.

(*b*) *Mycorrhiza—Pine Studies.*—(i) *Isolation of Mycorrhizal Fungi.*—Cultures have been obtained from fruiting bodies of several basidiomycetes found in plantations of *Pinus radiata* where they may be forming mycorrhizae. Slow growing fungi, isolated from the inner root, are being tested for ability to form mycorrhizae on *P. radiata* seedlings grown under aseptic conditions.

(ii) *Litter Decomposition.*—Studies commenced on factors affecting rate of breakdown of *P. radiata* litter and release of nutrients to trees. Decomposition is being followed by Warburg respirometry. Decomposition of the uppermost L layer was twice as fast as in the intermediate F layer and three to four times as rapid as in the bottom H layer.

(iii) *Root Profile Studies.*—Poor growth of *P. radiata* on laterite soils at Second Valley, South Australia, is being investigated. Observations are being made throughout the year on extent of root growth, both horizontally and vertically in the soil, and on the period of most active growth when mycorrhiza roots are at their maximum.

(*c*) *Rhizosphere Microorganisms—Plant Root Studies.*—(i) *Effect of Pasture Sward on Composition of Rhizosphere Microflora.*—Study was made of 273 bacterial isolates from the rhizospheres of subterranean clover and Wimmera ryegrass. These were grown together at high and low nitrogen levels to yield two types of sward, viz. clover dominant and grass dominant. Variability between replicate samples made it difficult to detect any possible difference. There were slight qualitative differences between groups, and plants from the high-nitrogen, grass-dominant sward supported higher proportions of isolates capable of glucose fermentation, starch hydrolysis, ammonia, and hydrogen sulphide release. Distribution of genera varied only slightly between groups of isolates from different sources.

(ii) *Root Exudate Studies.*—Excretion of growth factors by plant roots has been studied to obtain better understanding of stimulation of rhizobia and other microorganisms in the rhizosphere. Bioassay techniques were used to measure the quantities of each vitamin. Lucerne, white clover, field pea, tomato, and *Phalaris tuberosa* were used, and exudation measured for the first two weeks of growth. All plants exuded biotin, pantothenate, and niacin, but no measurable quantities of thiamine or pyridozine were detected. In all cases field pea exuded considerably more than the other plants.

(iii) *Identification of Rhizosphere Organism.*—Morphology, staining reactions, and biochemical activities of a rhizosphere bacterium with high pleomorphic tendencies were compared with closely related *Arthrobacter globiformis* and *Nocardia asteroides*.

(*d*) *Solubilization of Phosphate by Microorganims.*—Microorganisms produce organic acids which dissolve small amounts of rock phosphate, but this effect is slight compared with the dissolving action of sulphuric acid produced by thiobacilli oxidizing sulphur. "Sulphur-phosphate" granules have been prepared by compressing 1 part of flowers of sulphur with five parts of rock phosphate, roughly ground as for superphosphate manufacture. Thiobacilli may be used to inoculate these granules but many soils contain sufficient sulphur oxidizers to serve as inoculum. Glass-house and field tests are being conducted to compare this bacterial fertilizer with those manufactured by industry.

(*e*) *Humus Studies.*—(i) *Synthesis of Humic Acids.*—Humic acids have been prepared by oxidizing phenols, such as catechol, caffeic acid, chlorogenic acid, dopa, and tyrosine, with phenolases from plants and fungi in the presence of amino acids. These humic acids closely resemble those occurring in many soils and seem to consist of co-polymers or resins formed from condensation of quinones and amino acids. Most rapid resinification occurs when the concentration of reactants is high and pH maintained about 7. In soil it is considered that humic acid polymers must be formed rapidly otherwise microorganisms would decompose the oligomers.

(ii) *Resistance of Humic Acids.*—Humic acids, ranging from 0 to 5000 years of age by carbon dating, were extracted from New Zealand soil profiles consisting of four humus layers buried by successive showers of volcanic ash. The buried soils were porous and moist so the humus probably would have been undergoing decomposition after burial. Their humates were hydrolysed and the fragments separated and identified by chromatography. Numerous amino acids and phenols were found, and small numbers of acids, but very few sugars, amino sugars, indoles, or reducing substances. Humic acid appears very resistant to microbial attack.

(iii) *Red Pigment from Green Soil.*—Recently patches of green soil were discovered on Kangaroo Island, South Australia. A red organic pigment and two yellow pigments were extracted with a variety of organic solvents containing acetic acid. When the red pigment is sorbed on neutral clay of alumina, green or purple colours are obtained, resembling those in the soil patches.

6. Clay Mineralogy.

(Division of Soils.)

(*a*) *Structure of the Micas.*—It has been proposed, as a result of a detailed examination of the muscovite structure, that distortion of the oxygen network in layer-lattice silicates (mica and clay minerals) depends largely on dimensional misfit between various layers of the structure. It is clear that tetrahedral layers in such minerals may be either smaller or larger than octahedral layers, depending on isomorphous substitutions present. Progress has been made in understanding the relative frequency of occurrence of the more common muscovite polymorphs.

(*b*) *Phosphate Minerals in Soils.*—Gorceixite and related minerals were isolated and identified from soils of the south coast of New South Wales and the Merredin district of Western Australia. These occurrences, in reddish prairie, yellow podzolic, non-calcic brown, and lateritic soils, with parent materials of shale, sandstone, and acid gneiss (together with those occurrences reported earlier) indicate a widespread distribution of this family of phosphate minerals independent of parent materials of the soils.

In some soils the presence of gorceixite probably accounts for deficiencies in other elements besides phosphorus. These minerals have a structure which can accommodate a large variety of metal ions so that some trace elements in soils might be found in the minerals. Soils have been examined where all, or practically all, of their copper, chromium, and lead have been found in the phosphate mineral.

(*c*) *Iron Oxides of Soils.*—Distribution of iron oxide in soil profiles (as shown by colour) reveals pedogenic processes not easily observable in other ways. Study of the nature and behaviour of iron oxides in soil is prerequisite to understanding of soil development. There is evidence that iron oxides are important in influencing chemical and physical properties of a soil.

Iron oxides, often present in only small amounts, must be concentrated for effective study. Removal of clay minerals with hydrofluoric acid was the intial method of concentration. Iron oxides dissolve slightly in the acid, however, and boiling caustic soda was tried as an alternative method of removing silicates from clays. Caustic soda is effective in attacing kaolin or montmorillonite, but the degree of attack on illite is dependent on its crystallinity. Almost pure iron oxides have been separated from soils by this method.

(*d*) *Swelling Studies.*—For accurate observations during swelling of the clay mineral montmorillonite, a low-angle X-ray diffractometer was designed and constructed. Features of the diffractometer are (i) use of curved crystals to give a focused monochromatic beam; (ii) incorporation of soller slits to limit divergence of the X-ray beam; and (iii) use of scintillation counter as detector.

Knowledge of the behaviour of montmorillonite in the 8-400 Å range of swelling will increase understanding of fundamental forces between clay particles.

(*e*) *X-ray Spectroscopy.*—In fertility and pedology studies of certain Queensland soils and of terra rossa and rendzina soils in South Australia, hundreds of samples have been analysed for zinc and other elements.

At the request of Broken Hill Associated Smelters, Port Pirie, the suitability of X-ray spectroscopy was examined as a process control method of analysing ores and other materials encountered in smelting.

The most satisfactory methods of analysis involved fusion of the sample with borax to obtain uniformity, followed by direct analysis of the borax glass. Methods were developed to eliminate interference between elements normally causing large errors in samples of this nature. Lead, zinc, iron, manganese, antimony, arsenic, and copper could be determined to within 1 per cent. (or less) of the amount present over wide concentration ranges.

(*f*) *Pedology Studies.*—Clay mineral analyses were made in connexion with geochemical studies of Tasmanian soils developed on dolerite (see Section 3, Soil Chemistry) and to assist in studies of the origin and development of riverine and coastal soils of New South Wales.

Mineral analyses of deep (classic) laterite profiles from the coastal plain and plateau of Western Australia revealed unexpected results. Contrary to current ideas clay of the pallid zones is rarely pure kaolin.

Brown and yellow podzolic soils from Western Australia are being studied to elucidate their relationship to one another and to the very old laterites. Although the brown and yellow soils appear very different in the field, mineralogical and chemical analyses fail to show marked differences. An interesting feature of both soils is their high degree of weathering. The soils are regarded as comparatively young but (using concentration of zirconium as an index of weathering) they show great losses of all elements during soil formation from the parent rock. About 90 per cent. of rock is lost in forming surface soil; and this is of the same order as that lost by laterites formed on similar parent materials.

7. SOIL MICROPEDOLOGY.

(Division of Soils.)

(*a*) *Mineralogy.*—Previously mineralogical studies of coarser fractions of soil materials were confined to correlations of soils with parent materials from samples submitted by field pedologists. Such studies have now been made more systematic by selection of particular areas and problems for detailed examination. Results are encouraging.

(i) *Parna.*—Occurrences of parna in a restricted watershed near Henty, New South Wales, is being investigated. A geological map has been drawn from somewhat sketchy outcrop and soil layers have been examined mineralogically.

An attempt is being made to correlate occurrence of parna with percentage of quartz and felspar coated by red iron oxide. Positive correlation would permit assessment of parna contamination in riverine and colluvial materials. Counts for parna are higher than for riverine materials.

(ii) *Soils from Darling Downs.*—Investigations in the Darling Downs, Queensland, region are concerned with weathering of basaltic minerals and their contribution to soils overlying sandstone sediments. Field studies have shown as many as eleven flows to be present in the selected area.

(iii) *Soil Layers on Southern Tablelands.*—Preliminary investigations were made on soil layers from the lower slopes of Mt. Spring, Australian Capital Territory, to determine parent materials of the layers and degree of mixing of porphyry with sedimentary rocks as source material.

(*b*) *Fabric Studies.*—The system developed over the past three years for describing soil materials by fabric and structure has been used sufficiently to prove its value. It is especially concise in naming standard commonly occurring elementary and basic structures and fabrics.

(i) *K_2 Soils of the Riverine Plain, New South Wales.*—Study of structure in involving peds and planar voids in four soils from the riverine plain has been completed. For peds to be recognized as such, as units, they should be completely surrounded by either natural voids or cutans, that is, by recognizable natural surfaces. In profiles examined, with one horizon, such peds may be regular or irregular in size, shape, and arrangement, depending on arrangement of planar voids. In horizons lacking peds, or within peds, arrangement of planar voids determines the manner in which a soil material breaks down when subjected to deformation.

(ii) *Effects of Drainage on Fabric.*—Preliminary investigations have been made on the effect of drainage on fabric. Three profiles of K_3 age have been selected covering a range of drainage status. Good drainage tends to increase development of strongly oriented, depositional clay mineral cutans indicating clay illuviation. Poor drainage decreases their development but enhances development of stress cutans with striated orientation.

(*c*) *Weathering and Soil Genesis.*—(i) *Lateritic Ironstone Gravels.*—Mineralogical studies are being made on ironstone gravels from Western Australian lateritic soils to test a theory of protection from weathering of parts of the parent materials by coatings of iron oxides. Gravels from most profiles contain predominantly quartz. Microcline occurs with quartz in gravels from a profile on the youngest laterite surface but not from a profile on another surface thought to be the same age. Microcline, although thought less resistant to weathering than quartz, is one of the most resistant felspars.

(ii) Preliminary investigations are being made on three profiles formed on granodiorite from northern Queensland. If these studies indicate reasonable uniformity in parent material for any or all of these profiles a detailed study of weathering and profile formation will be made. Two of the profiles are latosols and the third is a red-brown earth. They cover a range in rainfall from 170 to 25 in. per annum.

8. SOIL MECHANICS.

(Soil Mechanics Section.)

(*a*) *Foundations.*—The principal foundation problems affecting building development in urban and rural areas are being defined and studied on a regional basis.

(i) *Shallow Foundations.*—Foundation problems for domestic-type buildings on clay soils in a winter-rainfall, summer-drought climate have been studied at Elizabeth, South Australia. Investigations are complete, but observations will be continued for a further twelve months. Limited investigation of a parallel nature commenced in the Wimmera region of Victoria.

Appreciation has been made of complementary problems of shallow foundations on clay soils in a summer rainfall zone, and experimental work has been planned for 1959/60 on an area in central Queensland.

(ii) *Deep Foundations.*—Foundation studies have been undertaken in the South Melbourne basin, an area of soft estuarine muds (approximately 100 feet deep) overlying a weathered silt stone (also of up to 100 feet thick). These provided opportunity for rationalizing, sampling, and testing procedures for such materials and helped to define the geotechnical problems of urban development in the area.

Studies in the substrata at Elizabeth, South Australia, have been continued on samples representing the upper 50 feet of an area of approximately 10 square miles to be used for domestic and industrial building.

(*b*) *Subgrade Moisture.*—Problems of moisture movements in pavement subgrades have been appreciated for many years and have been investigated to a limited extent. Funds from the major State road authorities will permit investigation of all important soil types and climatic regions in Australia. Work has commenced on design of equipment and selection of appropriate sites for field study.

Planning, co-ordination, and interpretation of a programme of field work have been undertaken by the Section with support from pedologists of the Division of Soils.

Collaboration with similar research groups in other countries is being sought to provide comparative data and independent assessments of experimental techniques.

(*c*) *Soil Stabilization.*—Study of soil stabilization techniques is continuing primarily as a research contract for the Department of Supply.

A collated account of overseas research and Australian experience of soil stabilization is being prepared. A comprehensive library of soil stabilization literature is being developed.

Following last year's decision to relate stabilization research to the pedological classification of soils, fourteen major soil types covering the Australian continent have been chosen. Facilities for bulk storage of soil samples have been established and a programme of soil selection and sampling has been commenced in collaboration with leading pedologists.

Investigations of empirical relationships between stabilization processes and pavement performance have been designed to follow the pattern of full-scale trials. The first trial has been planned in collaboration with municipal authorities and commercial organizations in the Melbourne metropolitan area. Fundamental investigations of the basic mechanisms of soil stabilization have been planned and will be undertaken when the necessary equipment is available.

(*d*) *Basic Soil Properties.*—Long-term studies of dependence of physical soil characteristics on stresses within the liquid phase have been extended to cover the theory of behaviour of non-saturated soils during sampling and during strength and consolidation tests.

Theoretical studies have been made of fundamental physico-chemical properties of clay systems in relation to corresponding engineering characteristics. A conference on interparticle forces in clay-water-electrolyte systems was well attended by physicists and chemists from universities and other branches of C.S.I.R.O. Experiments have commenced to define the engineering behaviour of homionic variants of simple clay minerals.

III. PLANTS.

1. GENERAL.

The Organization's main concentration of research on plants is undertaken at the Division of Plant Industry with head-quarters at Canberra. All returns from the land stem primarily from plants, either as pastures or crops, and the research of the Division relates to problems which are fundamental to agricultural production in Australia.

The Division of Plant Industry is the Organization's oldest Division, and its work is complementary to activities of the State Departments of Agriculture, which serve more immediate local needs of the farming industry. The Division has experimental farms and regional laboratories throughout the Commonwealth.

A major part of the Division's activities has for many years been concerned with the establishment, utilization, and maintenance of improved pastures throughout the diverse climatic regions of Australia. Research in agronomy, ecology, plant breeding, and plant nutrition has been pursued with the main aim of improving pastures. Work is also directed to other crops of economic importance, such as tobacco and wheat. Complementary to these activities, strong research teams have been established in genetics, microbiology, biochemistry, and plant physiology to undertake fundamental research on plants. The work of the Division of Plant Industry is described in this Chapter.

Allied work on mineral nutrition of plants carried out by the Division of Biochemistry and General Nutrition is described in Section 8 of this Chapter.

The work of the Fodder Conservation Section is reported in Section 21 of this Chapter, and that of the newly formed Wheat Research Unit in Section 22 of this Chapter.

Work on special local problems of irrigation disticts is undertaken by the Irrigation Research Stations at Merbein, Victoria, and Griffith, New South Wales (see Chapter IV.).

The Division of Entomology is carrying out work on biological weed control, insect pests of pastures and crops, and insect vectors of virus diseases (see Chapter IX.).

The Division of Soils is studying microorganisms in soil as they influence growing plants (see Chapter II.).

The Division of Land Research and Regional Survey is carrying out broad-scale ecological surveys to assess land use potential and investigate problems of agricultural and pastoral development. The work of these regional surveys is reported in Chapter XI., Section 2. The Division's investigations on crops, fertilizers, plant diseases, tillage, and native and introduced pastures under dryland cultivation at the Katherine Research Station, and under irrigation at the Kimberley Research Station, are reported in Chapter XI., Section 9.

In Chapter XXVII., Section 4, is recorded the work of the Division of Meteorological Physics on meteorological aspects of agricultural problems.

In Chapter XVI., Section 12, is recorded the work being undertaken by the Wool Research Laboratories on the digestibility of pasture plants.

In Chapter XVII., is reported the work of the Chemical Research Laboratories on alkaloids in Australian plants (see Section 7), the nature of chemical compounds exuded by the roots of growing plants (see Section 7), and stock poisons in plants injurious to animals (see Section 7).

Division of Plant Industry.—The announcement was made in June that the Brisbane group of the Division is from 1st July, 1959, to become the Division of Tropical Pastures with Dr. J. Griffiths Davies as Chief (see Chapter I., Section 6). The new Division will have its headquarters in Brisbane but will continue to work in association with the parent Division in Canberra.

The Division has moved into its new Experiment Station in Ginninderra, Australian Capital Territory. Development of the station is proceeding rapidly to transfer as soon as possible field work from the present Dickson Station, which is being taken over for Canberra housing projects.

The Agrophysics Section previously located at Deniliquin has been transferred to Canberra.

Design and construction has continued of the phytotron (see Chapter I., Section 18).

The Standing Committee on Agriculture at its fifty-fourth meeting recommended that an Australian Agrostology Conference be convened by C.S.I.R.O. This conference was organized and held at Armidale in December, 1958. One hundred and twenty-six delegates attended, representing industry, universities, Commonwealth Departments, State Departments of Agriculture, and the Organization. Seventy papers were presented.

A second "Plant Breeding Workshop" was held in Canberra in June and was attended by geneticists and plant breeders from universities, State Departments of Agriculture, and the Organization.

Mr. A. B. Costin and Dr. D. M. Moore visited Macquarie Island during November and December, 1958, to undertake phytogeographic studies and assess the effect of rabbit infestation on vegetation and soils. Herbarium, field material, and living specimens were collected and peat materal obtained for age determination of flora and vegetation. Only two stabilizing species exist in the small grassland flora, and they happen to be the most palatable species to rabbits. Rabbit grazing has therefore had a disastrous effect on the grassland.

Co-operation has continued in training schemes for F.A.O. and Colombo Plan Fellows, and the Division has collaborated in research programmes with the various universities, State Departments of Agriculture, and other Divisions.

2. PLANT INTRODUCTION.

(Division of Plant Industry.)

(*a*) *International Exchange.*—The year was a very active one for overseas exchanges, and more than 2,200 introductions of seed and other plant material were brought in for testing and distribution. This exceeds the number of introductions during any comparable previous period. The introductions included collections of plants made in Chile and other parts of South America by an officer of the Division, as well as large collections made in the Mediterranean region, Iran, and Afghanistan by Swedish botanists and generously supplied for trial. Pasture species were predominant, but many varieties of crop plants were also introduced for use by Commonwealth and State specialists. Annotated lists of plants introduced were distributed to collaborators within Australia, and resulted in many requests for seed for experimental use. Large collections of Australian and introduced plants were sent to agricultural research stations and botanic gardens in all parts of the world.

All incoming and outgoing plant material was critically examined and treated to comply with quarantine requirements.

(*b*) *Preliminary Testing*.—Most of the plants introduced were grown in quarantine nurseries at Canberra, Perth, and Brisbane, where growth and productivity studies were made, the plants checked for quarantine purposes, and seed built up for further agronomic and regional trials.

Although a large number of previously untested species were included in Canberra trials, they showed little promise with the exception of some varieties of *Secale montanum* from Hungary, which were especially noteworthy for autumn and winter growth. Several new varieties of established pasture species appeared attractive, including new introductions of lucerne from France, varieties of sainfoin from F.A.O. and from Hungary, and introductions of cocksfoot received through F.A.O.

At Brisbane, effort has been concentrated on the introduction and evaluation of pasture, forage, and pulse legumes from tropical and subtropical countries. The most promising pasture and forage species are in the genera *Phaseolus, Glycine, Vigna,* and *Desmodium*. An unusual species with considerable promise is *Lotononis bainesii* which grows both in summer and winter. Introductions of green and black gram (*Phaseolus aureus* and *P. mungo*) have not been satisfactory in south-eastern Queensland, but soybean introductions from low latitudes have maintained their early promise.

(*c*) *Agronomic and Regional Trials*.—Intensive studies have continued on species of *Phalaris* at Canberra, Perth, Armidale, and regional centres. Following a review of trials throughout the southern parts of Australia from Perth to northern New South Wales, seven introductions of *Phalaris tuberosa* from various parts of the Mediterranean region have been selected for seed multiplication and large-scale testing. All these introductions appear superior to the Australian commercial type in productivity and persistency under marginal conditions.

More recent introductions of *Phalaris tuberosa*, especially from the Aegean region and Crete, have proved unproductive at Canberra, but may be useful in more arid areas. Some hybrids between *P. tuberosa* and *P. arundinacea*, including types known in South Africa as Ronpha grass, have outyielded commercial *Phalaris* over a wide range of environments.

Other species under study at Canberra include introductions of *Bromus inermis* and lucerne. In Western Australia similar studies are in progress on cocksfoot, vetches, and annual clovers. Among the latter, bladder clover (*Trifolium spumosum*) and rose clover (*T. hirtum*) are becoming established commercially, while *T. clypeatum* and *T. cherleri* continue to show promise.

A large range of introduced grasses, mainly from South America and Africa, have been tested under grazing at several localities in southern Queensland for five years. A number of these, particularly in the genera *Panicum, Chloris,* and *Setaria,* proved superior to indigenous and naturalized pasture grasses in most areas with rainfall greater than 20 inches. In coastal regions, introduced species of *Paspalum, P. plicatulum, P. scrobiculatum,* and *P. notatum,* proved superior to naturalized *P. dilatatum*. Another potentially valuable grass in coastal areas is *Echinochloa pyramidalis*.

(*d*) *Plant Geography*.—Studies continued on distribution of the genera and larger groups of grasses throughout the world, and papers have been published dealing with the tribes Andropogoneæ and Paniceæ. Study has been completed of the subfamily Eragrostoideæ, which occurs mainly in arid areas of Australia, South Africa, and parts of the northern hemisphere. A close relationship exists between grass distribution and climate, providing a useful floristic basis for comparison of regions in different parts of the world, and throwing light on evolution of the grass family.

A detailed comparison has been made between the climates of Australia and the Mediterranean region, with particular emphasis on length of growing season. This work will provide a basis for understanding the performance in Australia of ecotypes of *Phalaris* and similar grasses, and indicate probable limits of their potential cultivation here. Mediterranean collections of *P. tuberosa* grown at several localities in Australia have shown that temperature-growth rate interactions, low temperature-floral induction controls, and high temperature tolerance are all of importance in determining survival and production of the species.

3. GENETICS AND PLANT BREEDING.

(Division of Plant Industry.)

(*a*) *Subterranean Clover*.—(i) *Subspeciation*.—Analysis continues of genetic incompatibilities within the species.

(ii) *Natural Selection Plots*.—Mixed hybrids and parental pure lines were sown at seventeen locations to follow the effects of natural selection. At Deniliquin hybrids again are more competitive than pure breds.

(iii) *Seed Dormancy*.—The function of the embryo is being examined by progeny tests from dormant and non-dormant seeds from an F_1 plant. Embryo dormancy has usually been considered transitory, disappearing after a few months. Differences in dormancy between strains have been found in seed up to five years old.

(iv) *Selection for Sward Productivity*.—Swards consisting of fifteen selected hybrids, eleven Australian strains, and 34 recent introductions, planted in 1956, were sampled this year. One of the selections yielded 25 per cent. more dry matter in the August harvest than did Bacchus Marsh—the best commercial strain. This hybrid is also resistant to rust and stunt virus.

No recent introduction yielded greater than 70 per cent. of Bacchus Marsh early in the season, but some late strains from Greece and Portugal yielded well in late spring. Selections are being established as swards for further yield trials. The more promising lines are under test at Kojonup, Deniliquin, and Bathurst.

(v) *Resistance to Subterranean Clover Stunt Virus* (in collaboration with the Division of Entomology).—In a survey of 320 strains, only three (Tallarook, Hills Small, and Bass) were found to be markedly resistant. Selections from various hybrid derivatives of Tallarook are now being tested for resistance. A mid-season line selected from an F_2 of Tallarook x Northam First Early has proved highly resistant.

(*b*) *Lucerne*. (i) *Winter Yield and Creeping Rootedness*.—Seedling progeny from crosses between winter growing strains and creeping-rooted lines are being selected for creeping-rooted habit using the glass-house test reported last year. Selections responding to this test are being further selected in the field for productivity and creeping-rooted habits. The role of environmental factors in the stimulation of creeping rootedness is being studied.

(ii) *Inheritance of Creeping Root*.—In collaboration with the Canadian Department of Agriculture, analyses are being made of data obtained by Dr. D. Heinrichs at Swift Current, Saskatchewan. Most genetic variation appears additive.

(iii) *Cold Hardiness and Winter Growth*.—Analysis of F_1's indicates that mass selection for cold hardiness could be effective. Extended light treatment (eighteen hours) had a significant effect ($P < 0.001$) on dry matter production, but not on level of cold hardiness.

(iv) *Strain Trials*.—At Canberra Du Puits has greater summer production than Hairy Peruvian, Hunter River, Caliverde, and Rambler in that order. But in winter

Hairy Peruvian yielded 100 per cent. more than Hunter River or Caliverde, Du Puits gave less than Hunter River, and Rambler was dormant. At Deniliquin in the second year of heavily grazed swards there was no change in density of plants on dry-land swards, but under irrigation differences in density are now becoming apparent. Hairy Peruvian produces more than Hunter River in winter and summer, and, to a lesser extent, in autumn but not in spring. The pattern of production may indicate that Hairy Peruvian lacks winter dormancy and is more tolerant of high temperatures than Hunter River.

(*c*) *Barrel Medic.* (i) *Preliminary Physiological Studies on Influence of Temperature.*—Thirty-six strains showed 95-100 per cent. germination at constant temperatures in the range 1-28° C. Ten strains were grown at three mean temperatures—17, 21.6, and 23.6° C. Strain differences were found in the influence of temperature on relative growth rate (R), net assimilation rate (E_a), and percentage increase of total plant dry weight. Most of the strains gave highest values at the intermediate temperature indicating a marked response to a critical temperature in the narrow range 21.6-23.6° C. One strain from Greece and one from Morocco had a greater range of heat tolerance than the other strains tested.

(ii) *A Crossing Programme.*—Crossing trials of 36 strains reveal a high degree of interstrain incompatibility: in most cases degeneration of the ovule and abortion occurred 5-10 days after fertilization.

(*d*) Phalaris.—(i) *Interspecific Hybridization.*—Last year, experiments were outlined for the production and testing of extensive synthetic alloploids of *P. tuberosa* x *P. minor* and *P. tuberosa* x *P. arundinacea.* Material for these experiments produced rapidly, so that field trials will be commenced next year.

(ii) *Top Crossing in P. tuberosa.*—Twenty-eight selected introductions have been top crossed to commercial *P. tuberosa* and to one introduction. Progeny will be established in the field this year as both single plants and swards.

(iii) *Genome Analysis in the Genus* Phalaris.—The evolutionary pathways and relationships between the species are being studied in a series of interspecific hybrids. The relative ease of hybridization between different species is being determined. Cytological studies are being made on hybrid, polyploid, and haploid material.

(iv) *Breeding Structures of* P. tuberosa.—Improved crossing techniques based on detection of incompatible pollinations have been developed. These depend on the staining behaviour of pollen on the stigma, and use of dominant seedling marker genes. They allow detection of three major breeding groups in *P. tuberosa*, viz. strongly self-incompatible, weakly self-incompatible, and self-compatible.

(v) *Physiological Studies.*—As a preliminary to phytotron studies, the effect of temperature and day length on winter production and the effect of non-flowering in the spring on vegetative vigour are being studied.

(*e*) *Pasture Plant Breeding at Wagga.*—Agronomic and breeding studies have been initiated to overcome deficiencies in autumn and winter productivity, and to achieve a better grass-clover balance for short-term leys in the wheat belt.

(i) *Evaluation of Perennial Grasses.*—From spaced plant trials with *Phalaris tuberosa*, *P. coerulescens*, *Dactylis glomerata*, *Lolium perenne*, *Ehrharta calycina*, and *Hordeum bulbosum*, the most productive strains have been selected and these are now being compared under sward conditions.

(ii) *Summer Growing Perennial Grasses.*—Strain trials have been established with *Panicum coloratum*, *Phalaris arundinacea*, *Bromus inermis*, *Festuca arundinacea*, and *Phelum pratense.* Summer yield and winter persistence will determine strains for test in swards.

(iii) *Seed Size and Seedling Vigour in* Phalaris tuberosa.—Within a strain, seedling vigour is directly related to seed size. Large differences exist between the two strains tested (Australian commercial and Morocco C.P.I. 19305) and show that part of the seedling vigour is genetically determined and independent of seed size.

(*f*) Hordeum bulbosum.—(i) *Production of Awnless* Hordeum Bulbosum *Genotypes.*—Attempts have been made to induce awnless mutants in *H. vulgare.* Screening in the first generation after treatment has not revealed dominant mutants; recessive mutants will be sought in subsequent generations.

(ii) *Incompatibility in* H. bulbosum.—Preliminary studies of diploid *Hordeum bulbosum* suggest gametophytic control of incompatibility.

(*g*) *Cytology and Cytotaxonomy.*—(i) Themeda australis.—Studies are complete on distribution of chromosome races of *Themeda australis* in southern Australia. Further studies will be made on material from northern Australia.

(ii) Danthonia *Species.*—Cytotaxonomic studies in Australian *Danthonia* species have been completed.

(iii) *Chromosome Numbers of Macquarie Island Flora.*—Preliminary survey of chromosome numbers of plants from Macquarie Island is in progress using material collected on an expedition in December, 1958. Chromosome numbers have been determined for 17 of 31 angiosperm species.

(*h*) *Radiation Genetics.*—(i) *Blue Mould Resistance in Tobacco.*—*See* Tobacco Investigations (Sections 15).

(ii) *Root-knot Nematode Resistance in Tomatoes.*—A number of mutants have been selected which are resistant to the common strain *Meloidogyne javanica.* A strain of nematode has been isolated capable of overcoming all resistant mutants. Screening is in progress for resistance to this strain of nematode.

(iii) *Flowering Time Mutants in Subterranean Clover.*—An M_2 population of Tallarook subterranean clover had a significantly increased variability in flowering time. The earliest flowering mutant flowered seven days before the earliest flowering control and the latest flowering mutant eleven days later than the latest control.

The total variance in the M_2 population increased with dose, both within and between family components increasing linearly with dose, except for a plateau at the highest dose.

Variation in flowering time was independent of morphological or other visible variation.

(*i*) *Developmental Genetics.* — (i) *Biotin-deficient Mutants of Arabidopsis.*—The genetics and physiology of two races requiring biotin for growth at temperatures above 28° C. In both races the biotin requirement is determined by a single recessive gene. Both mutant genes fail to carry out the conversion of desthiobiotin to biotin. These genes appear identical yet their phenotypic effects, and dose and temperature response curves of plants carrying them, are different.

(ii) *The Physiological Activities of Polygenes.*—A study is being made of the biosynthetic sequence leading to the formation and utilization of *p*-aminobenzoic acid, in *Arabidopsis thaliana.* Sulphanilamide, a competitive inhibitor of *p*-aminobenzoic acid, is used as a tool to dissect this sequence into portions to be evaluated genetically.

(iii) *Recombination in the Tomato.*—Recombination frequently is influenced by age, position on the plant, growing condition, chemicals, and genetic background.

(*j*) *Quantitative Genetics* (Arabidopsis thaliana).—(i) *Temperature Lesion Studies.*—Five out of 43 races of *Arabidopsis thaliana* were extremely sensitive to high temperature, but growth rate was restored to normal by addition to the medium of such substances as biotin and cytosine.

(ii) *Genetic Study of Homeostasis.*—Forty races have been grown at six temperature regimes to define measurable homostatic parameters.

(iii) *Interaction of a Major Gene with its Modifier Complex.*—This is being studied in crosses between an early and a late flowering race exhibiting an allelic difference for a locus which has a large effect and also modifier complexes.

4. GENERAL BOTANY.

(Division of Plant Industry.)

(*a*) *Structural Botany.*—Studies continued of early ontogenetic development and histogenesis of monocotyledonous flowers. Examination is nearing completion of *Bulbine bulbosa, Lomandra longifolia,* and *Stypandra* spp. of the family Liliaceae. In this family difference in mode of origin between "foliar" and "cauline" parts of the flower is not so well marked as in Juncaceae and much less marked than in Gramineae and Cyperaceae.

(*b*) *Taxonomy and Systematic Botany.*—A paper dealing with "The Phytogeography of the Australian Region" has been prepared, utilizing basic data obtained in the preparation of a Dictionary of Australian Plant Genera. The phytogeographic study is a comprehensive and integrated survey, providing basic information on the origin and evolution of the Australian flora.

Work has progressed on preparation of a "Flora of the Australian Capital Territory", to be published under sponsorship of the Royal Society of Canberra, and will be valuable to all botanists working in the region.

Field collections in the northern and central parts of Western Australia, included specimens and seeds for taxonomic studies and plant introduction exchanges. Attention was given to the collection of material of the genus *Nicotiana*, and at least two new species were discovered in the Pilbara district. Collections were also made around Mount Kosciusko and on the south coast of New South Wales.

5. MICROBIOLOGY.

(Division of Plant Industry.)

(*a*) *Phytopathology.*—(i) *The Basis of Disease Reactions.*—Experiments to test the phytoalexin theory of plant disease resistance continued. These studies aim to determine whether toxins formed by the plant after fungal infection, or released as a result of host-pathogen interaction, constitute a general basis for disease resistance mechanism in plants. Pea pods were inoculated with a pathogen (*Ascochyta pisi*), a non-pathogen (*Sclerotinia fructicola*), and water. Concentration of toxin in diffusate from pods was greatest for the non-pathogen, less for the pathogen, and smallest for water. This order of toxin difference was obtained over a period of 48 hr. The same substance was produced irrespective of type of inoculum. Experiments *in vitro* showed that the sensitivities of *Ascochyta pisi* and *Sclerotinia fructicola* to a given concentration of purified aqueous extract of the toxin are significantly different; *S. fructicola* was the most sensitive. Trace quantities of a colourless oil have been isolated from diffusates and aqueous solutions of this substance exhibit antifungal activity. Other chemical properties have been studied by solvent extraction, paper chromatography, and spectrophotometric analysis.

The physico-chemical basis of plant disease reaction to *Alternaria solani* infections is being studied. This work should provide information on the parts played by toxin production, genetic variation in the mould, and factors affecting resistance of host plants in disease development. Many strains of the pathogen have been isolated and defined in terms of morphology, cultural characteristics, growth requirements, metabolite production, and pathogenic behaviour. Work is in progress to isolate and characterize various toxins produced by these strains. Satisfactory assay methods for two of the toxins produced *in vitro* have been developed.

(ii) *Establishment of Virus Infections.*—The early stages of infection of tobacco mosaic virus in *Nicotiana glutinosa, N. tabacum,* and *Phaseolus vulgaris* var. Pinto are being examined using biological assays for infectivity. Studies on virus establishment following different methods of inoculation are included. When leaves are inoculated the virus concentration decreases before it increases. To obtain information on these phases of infection, virus inactivation is being studied *in vivo* and *in vitro*.

(iii) *Viruses of Pasture Plants.*—A survey is being initiated to determine the presence and prevalence of virus diseases of native and improved pastures.

(*b*) Rhizobium *Investigations.*—Investigations to ascertain host influence on the ecology of nodule bacteria in legume rhizospheres are in progress. Attention is being given to subterranean clover (*Trifolium subterraneum* L.) and to the relation of effective nodule bacteria in the rhizosphere to early effective nodulation.

Under certain conditions grass in mixed pastures of grass and subterranean clover fails to grow properly and the subterranean clover becomes dominant. Greater nitrogen production by the clover might stimulate better growth by the grass. The capacity is therefore being studied of host varieties to support desirable nodule bacteria in their rhizosphere, to nodulate promptly, and to symbiose effectively with standard strains of nodule bacteria under commonly encountered field conditions. At the same time the principle of applying stresses to the symbioses is being used to find strains of nodule bacteria best able to maintain nitrogen fixation under suboptimal conditions for plant growth. Similar studies are being undertaken with annual species of *Medicago*. Annual medics are the only pasture legumes available over very large areas of inland Australia. The prime objective is better nitrogen fixation by barrel medic (*Medicago tribuloides* Desr.) under adverse climatic conditions, than that possible with presently available material.

The culture collection of *Rhizobium* strains is being maintained and increased. Introduced legumes for which effective *Rhizobium* strains have been found during the year are *Chamaecrista fasciculata, Hedysarum coronarium, Lathyrus ochrus, Lotus maroccanus, Onobrychis sativa, Ornithopus sativus, Trifolium ochroleucum, Trifolium squarrosum, Trigonella arabica,* and *Trigonella foenum-graecum.*

Experiments with methods of inoculating seed have shown that pelleting with bentonite and organic materials is not as effective as was previously suggested; experiments are continuing. Chemical Research Laboratories are collaborating to determine the fraction of the root secretions of *Trifolium subterraneum* important in stimulating nodule formation.

6. GENERAL CHEMISTRY.

(Division of Plant Industry.)

(*a*) *Soil Fertility.*—Factors concerned in changes in soil fertility under leguminous pastures are being examined at Crookwell, New South Wales. Together with increases in available nitrogen, phosphorus, sulphur, calcium, and magnesium, there are increases in exchangeable potassium in these soils as a direct result of pasture improvement. This build-up in exchangeable potassium plays an important part in overcoming potential potassium deficiency in the soil studied. The range 0.25-0.30 m.-equiv. of exchangeable potassium per hundred grains of soil is a critical level in these soils.

(*b*) *Sulphur Availability.*—Studies on the chemical nature of sulphur in slightly acid soils from eastern Australia have led to the development of a satisfactory method for the laboratory assessment of plant-available sulphur. Previous studies have shown that in acid, well-drained soils practically all soil sulphur is present as organic forms and measurement of total soil sulphur gives little or no indication of the amount of plant-available sulphur. Laboratory investigations of chemical fractions of the soil sulphur have shown that the small and variable amounts of free sulphate in soils generally do not provide a satisfactory index of plant-available sulphur. Small amounts of soil sulphur are rendered water-soluble by gentle heat treatment. The total amount of water-soluble sulphur after the soil has been heated with water on a boiling water bath and then dried in a hot-air oven gives a good index of plant-available sulphur as measured by sulphur uptake and plant yield in pot culture.

(*c*) *Phosphorus Availability.*—Examination of a wide range of soils has shown that organic phosphorus, although correlated with carbon and nitrogen, varies more widely than sulphur, and part of the organic phosphorus may not be closely associated with carbon, nitrogen, and sulphur in soil organic matter.

Organic phosphorus, often comprising a major proportion of total soil phosphorus, has only low availability to plants. Investigations into the chemical nature of this important fraction of soil phosphorus have continued using chromatography and electrophoresis. In the majority of soils examined inositol phosphates comprise only a small proportion of the total organic phosphorus.

(*d*) *Spectrochemical Investigations.*—Work on the application of atomic absorption spectroscopic analysis to agricultural samples has continued. This method has advantages over other methods, both chemical and spectrochemical, for the determination of several elements of agricultural interest—particularly magnesium, zinc, calcium, sodium, and potassium. Satisfactory methods using this technique have been devised for the determination of each of these elements in plant material and the technique has also been adapted for determination of exchangeable cations in soils. With present equipment analysis is possible down to a concentration of 0.1 p.p.m. in solution for sodium, 0.2 p.p.m. for potassium, magnesium, and zinc, and 0.5 p.p.m. for calcium.

(*e*) *Availability of Manganese and Molybdenum.*—Studies are being made of factors influencing availability to plants of soil manganese and molybdenum.

The effect in neutral soil of lime additions on the uptake of manganese by plants and the influence of this treatment on the manganese cycle in the soil are being examined. Reversion is also being studied of manganese from available to unavailable forms.

Chemical studies and pot experiments are being made to assess the effect of iron and aluminium oxides on availability to plants of both native and applied molybdenum. A similar examination is being made using a wide range of molybdenum deficient soils to assess the value of chemical extractants for measuring available molybdenum.

Studies commenced on the role of silicon in living organisms.

7. PLANT NUTRITION.

(Division of Plant Industry.)

(*a*) *Soil Fertility.*—Experiments conducted on Southern Tableland soils have shown that superphosphate is an important source of calcium for subterranean clover. The lime required to correct calcium deficiency on some of these soils is being investigated.

Experiments to measure effects of clover on soil fertility, and residual effects of phosphorus and sulphur, have been maintained.

(*b*) *Nitrogen Fixation.*—(i) *Effects of Calcium.*—A study of the role of calcium in the nutrition of the clover plant has revealed that calcium has a specific effect on symbiotic nitrogen fixation. Under conditions of mild calcium deficiency the yield of clover was low, percentage protein and percentage non-protein nitrogen was reduced, and the plants were pale green. These effects are similar to the effects of sulphur and molybdenum deficiency. The nodules of calcium deficient plants showed signs of degeneration. Application of nitrogen fertilizer or calcium caused plants to become dark green and increased yield, percentage nitrogen, and percentage non-protein nitrogen. Mild calcium deficiency therefore induced nitrogen deficiency in clover plants by inhibiting nitrogen fixation.

With severe calcium deficiency, growth of the host plant was stunted by calcium deficiency rather than by nitrogen deficiency. These plants showed typical symptoms of calcium deficiency, and responded to calcium but not to nitrogen.

(ii) *Effects of Temperature.*—Moderately high temperatures exert a specific inhibitory effect on symbiotic nitrogen fixation. Nodulated clover plants were stunted and fixed inadequate amounts of nitrogen when grown in pots placed in temperature controlled water-baths at 30° C. Corresponding plants treated with nitrogen grew well and were a normal green colour. Normal growth occurred also where plants were grown at 20° C. Effects of temperature on clover thus vary depending upon whether the clover is provided with nitrogen fertilizer.

The reason for these effects is being examined. Additions of sucrose did not increase the amount of nitrogen fixed. The inhibitory effect of high temperature is therefore not due to decrease in supply of soluble carbohydrate to the nodule.

It is not known whether effects of high temperature on symbiotic nitrogen fixation are important under field conditions. In glass-houses symbiotic nitrogen fixation is restricted in warmer weather, and this can markedly affect the response of clover to nutrient treatments.

(*c*) *Role of Elements in Plants.*—A nitrate reductase enzyme coupled specifically to reduced diphosphopyridine nucleotide (DPNH) has been isolated from germinating wheat seedlings. This enzyme differs from known plant nitrate reductase in pyridine nucleotide specificity, pH optimum, affinity for substrates, and sensitivity to some inhibitors. In the absence of nitrate the enzyme is present at about one-third the level found in the presence of nitrate. A triphosphopyridine nucleotide linked nitrate reductase appears in wheat plants about four days after germination. Only the DPNH linked nitrate reductase appears to be present in pre-germinal and young post-germinal embryos.

Study of the effects of nutrition on changes in physiological and morphological characters of plants is being continued.

8. MINERAL NUTRITION OF PLANTS.

(Division of Biochemistry and General Nutrition.)

Studies employing radioactive zinc to determine the location and movement of zinc in subterranean clover plants has been completed.

Results confirm that once zinc is deposited during growth and development its redistribution among living parts is strictly limited even when subsequent imposition of zinc deficiency retards growth and leads to malformation of developing leaves. There is an appreciable transport of zinc from senescent leaves, and the amounts and concentrations of zinc in individual leaves may differ widely at any time during onset of zinc deficiency. Immediately after absorption zinc moves directly to centres of active growth. Scarcely any reaches fully developed leaves except during initial stages of recovery from serious zinc deficiency, when some newly absorbed zinc reaches all parts of the plant, including any " little leaves " which are alive at the time. These latter do not recover, however; recovery of the plant depends on production of new leaves by leaf primordia.

Research continued to relate zinc content of parts of subterraneon clover plants to the zinc status of the plants. Earlier recognition of incipient zinc deficiency in this species than possible at present, appears essential to further progress in this direction. Study to enable recognition of the earliest morphological changes accompanying onset of zinc deficiency is in progress. Further work on diagnosis of impending zinc deficiency by microchemical means was deferred until this study has been completed.

Reports in the literature of marginal accumulation of certain mineral elements absorbed by plants, and a loss of minerals from leaves by excretion or leaching, have suggested that accumulation of cobalt by plants, its movement to leaf margins, and possible loss from the living plant, should be examined. Following preliminary work on uptake of ^{60}Co by subterranean clover growing in culture solutions, investigation has now commenced on factors affecting loss and replenishment of cobalt in leaves of subterranean clover and *Phalaris tuberosa.*

9. Plant Physiology.

(Division of Plant Industry.)

(*a*) *Seed Germination.*—(i) *Wimmera Ryegrass* (Lolium rigidum *Gaud.*).—At commercial maturity the seeds show a short-lived dormancy which may be broken by low temperature treatment. In the first storage year seeds are more adversely affected by high temperatures than in the second year. Apart from this, laboratory germination is normal and easy, and disappearance of Wimmera rye from old pastures may be due to difficulties of establishment or management, rather than germination.

(ii) Anagallis arvensis *L.*—Further study of this light-sensitive seed has shown that control exercised by the red/near infra-red pigment system is dependent on: (1) post-harvest age of seeds; (2) length of imbibition period prior to irradiation; (3) an interaction of (1) and (2); and (4) temperature.

(*b*) *Seedling Growth.*—All developmental and physiological processes appropriate to vegetative growth are represented in the seedling, and the relative simplicity of the organism at this stage makes it an appropriate test object for study of growth. Analysis of results for wheat seedlings has been completed, revealing a complex pattern of interdependent change for successive organs as they rise. Individual leaf primordia pass through a slower phase (cell division) and then a faster phase (mainly cell expansion) of exponential growth before emergence. The study emphasizes the importance of these very early events in determining later development.

(*c*) *Inflorescence Development.*—Experiments with two differing approaches have been carried out. In the first series, manipulation of such features of external environment as temperature and length of day has resulted in changes in the pattern of inflorescence differentiation *in vivo* in speltoid wheats, *Lolium perenne*, and *Cynosurus cristatus.* In the second series, attempts to culture very early stage wheat inflorescences *in vitro* have continued. Gibberellic acid (10 p.p.m.) induced elongation of the lower internodes, and of the glumes of the lower spikelets.

(*d*) *Flowering in Long-day Plants.*—(i) Lolium temulentum.—The sensitivity of *Lolium temulentum* plants to induction by long days increases with age until the sixth leaf is unfolded, by which time only a few square cm of leaf need be exposed to one day of continuous light for induction to occur. The flower-promoting substance produced in this leaf is translocated from it during the following day. The light-requiring promotive process is not photosythesis, since it proceeds at intensities of only 1 foot-candle, but it requires active photosynthesis to precede it. It does not proceed at low temperatures, and has an optimum of 20° C. If other leaves are kept in short days at the same time, they produce a substance which is also translocated the following day, but which inhibits flowering and acts in antagonism to the other.

(ii) Lolium perenne.—This plant flowers in longs days, the number required depending on the extent of prior low temperature vernalization. When this latter process is incomplete, vernalization by short days can occur.

(*e*) *Nodulation in Legumes.*—For studies on nodulation behaviour, legumes are often grown in media of limited volume. Previous experiments showed that under these conditions auxin accumulates in the medium. To study influences upon nodulation of this auxin and other growth regulators which might accumulate, such substances were incorporated into agar on which lucerne plants were grown. High concentrations of the auxin naphthaleneacetic acid and of tryptophan delayed nodulation and the former also reduced nodule number. An antiauxin (ρ-chlorphenoxy*iso*butyric acid) increased nodule number and volume per plant. Auxin produced by nodule bacteria may limit the number of nodules produced by legumes grown on media of limited volume. Gibberellic acid delayed nodulation and greatly reduced nodule number. This suggests that caution should be exercised in attempting to stimulate pasture production with gibberellic acid sprays.

(*f*) *Protein Synthesis in Developing Wheat Grains.*—Developing wheat grains were sampled on fifteen occasions at four-day intervals, and analysed for fresh weight, dry weight, total nitrogen, and soluble nitrogen " albumin " and " gliadin ". Albumin synthesis preponderated in the early stages. Gliadin appeared later and became constant coincident with total nitrogen and dry weight. The ratio of amide nitrogen to total nitrogen of the gliadin fraction remained constant over all harvests, suggesting that " gliadin " represents a chemically homogenous fraction. The peak of activity of the enzyme glutamyl transferase coincided rather with that of albumin synthesis, and not with that of the later peak in gliadin synthesis.

(*g*) *Properties of Cellulose in Pasture Plants* (in collaboration with the Division of Protein Chemistry, Melbourne).—See Chapter XVI., Section 12.

Differences between the *in vitro* digestibility of cellulose preparations derived from different species are largely accounted for by degree of crystallinity of the cellulose and amount of pentosan present in the preparation.

(*h*) *Drought Hardiness.*—Since drought hardiness implies ability of plant protoplasm to survive desiccation, some properties of the protoplasm of hardened and non-hardened plants have been investigated in the hope of revealing informative differences. No differences have been detected in fine structure of cytoplasm as revealed by the electron microscope, the activity of some enzyme systems, and the amount of carbohydrate-protein complexes, which can be ascribed to the process of hardening.

10. Biochemistry.

(Division of Plant Industry.)

(*a*) *Biochemical Morphogenesis in Plant Tissues.*—The methods of isolated organ and tissue culture are being utilized to study biochemical processes underlying induction of cell division, cell enlargement, and cell differentiation.

(i) *Lateral Root Induction.*—In the isolated flax root, indoleacetic acid (IAA) induces cell division in the pericycle parenchyma adjacent to the protoxylem, and this act of induction is potentiated by the meristematic tissue of pre-existing primordia. The postulate is made that the meristematic cells of the original primordium produce or contain a kinin, which in the presence of IAA can induce cell division, and that such division is accompanied by further kinin formation. A bioassay is being devised to determine this kinin in extraction and purification procedures.

(ii) *Cultivation of Isolated Tissue from the Stelar Parenchyma.*—A technique has been devised for cultivation of isolated tissue from the stelar parenchyma of the flax root. This tissue *in situ* gives rise to the entire secondary root system, and to all secondary tissues of the whole root system, through initiation of lateral root primordia and cambium respectively. Isolated tissue is being prepared to examine these two processes, and to adapt it for bioassay of the kinin of Sub-section (i).

(iii) *A Kinin from the Apple Fruitlet.*—Extracts from apple fruitlets in the cell division phase of growth promote cell division in mature cells (apple cortex, tobacco pith, geranium pith, carrot root secondary phloem). Extracts from mature apples do not. The bulk of the activity resides in the receptacle. Auxin is required for activity. Chemical properties and fractionation behaviour of the active factors are being studied. The possible role of this kinin in the development of the apple fruit is being considered.

(*b*) *Studies of Tobacco Mosaic Virus (TMV).*—(i) *Determination of Nature of Terminal Nucleotide of TMV—Ribonucleic Acid.*—Attempts to identify the terminal nucleotide by removal of its monoesterified phosphate group, followed by alkaline hydrolysis of the ribonucleic acid, have revealed unexpected difficulties. These are attributed to the presence of minute traces of ribonuclease in both virus and phosphomonoesterase preparations. Normal purification procedures such as tryptic digestion and acid precipitation have failed to remove contaminating enzyme from the virus.

(ii) *Effect of Chloraphenicol on TMV-Protein and TMV-Ribonucleic Acid Synthesis.*—Chloramphenicol (CAP) is a specific inhibitor of protein synthesis. Its effects on synthesis of the protein and ribonucleic acid portions of TMV are being studied by a variety of methods.

CAP inhibits lesion production *in vivo* in *N. glutinosa* by TMV when the virus was suspended in the inhibitor at the time of inoculation. There was no inhibition of lesion formation when inhibitor was applied to leaves after inoculation with virus.

(*c*) *The Oxidation of Inorganic Sulphur Compounds by Soil Microorganisms.*—Oxidation of tetrathionate by *Thiobacillus* X, for short periods of time, leads to extensive formation of sulphate together with compounds with properties similar to those of thiosulphae, trithionate, and pentathionate. Oxidation of tetrathionate by " aged " cells is dependent on the presence of a trace of thiosulphate, or on a preincubation with tetrathionate under anaerobic conditions. Anaerobically, tetrathionate is metabolized to a compound with some properties of thiosulphate, sulphate, trithionate, and pentathionate. In addition about 10 per cent. of " volatile " sulphur is formed.

Attempts are being made to establish the reaction mechanisms responsible for the production of these compounds.

(*d*) *Phosphate Solubility and Decomposing Organic Matter.*—Increase in soluble phosphate, observed during decomposition of rice hulls in the presence of sparingly soluble phosphates, is due to release of phosphate from the the hulls themselves, to enhanced hydrolyses of ferric and aluminium phosphate, and to interaction between the silica of rice hulls and aluminium phosphates.

The mechanism by which ferric phosphate is dissolved during anaerobic decomposition of clover was investigated further, and both direct chemical and microbiological reactions may be involved.

(*e*) *Structure and Properties of Plant Photoreceptors.*—In the plant, the photoreceptor pigments are associated with specific proteins. Preliminary to studies of structure and properties of these chromoproteins, methods for their extraction and isolation in their native, functional forms are being investigated. Of a number of neutral detergents tested, digitonin has proved the most efficient for dispersing protein-chlorophyll complexes into true solution.

Active prepartions of the protochlorophyll complex of etiolated beans leaves have been obtained by extraction with glycine buffer containing 30 per cent. of glycerol. The active protochlorophyll complex has been partly purified by fractionation with ammonium sulphate and by ion-exchange chromatography and zone electrophoresis.

(*f*) *Haemoglobin and other Pigments of Soybean Root Nodules.*—Cytochrome *a*, found in the vegetative form of *Rhizobium* but not in the symbiotic (bacteroid) form, is not related to cytochrome oxidase as previously suspected. Studies on the inhibition of respiration with carbon monoxide (CO) and its reversal by strong light indicate that classical cytochrome *c* oxidase is absent from both forms of *Rhizobium*. Difference spectra (reduced + CO *v*., reduced) of *Rhizobium* suspensions show the presence of a CO-sensitive pigment very similar to leghaemoglobin, but no cytochrome oxidase.

Disruption of bacteroids by sonic oscillation yields extracts containing cytochrome *c* and a trace of the CO-sensitive pigment. A larger amount of CO-sensitive pigment is obtained when insoluble residues from sonic oscillation are extracted with cationic detergents. Considerable purification of the cytochrome *c* and CO-sensitive pigments has been effected by ammonium sulphate and acetone fractionation.

The relationship of these pigments to the primary nitrogen fixing enzyme of the legume nodule, and to the terminal oxidase system of *Rhizobium*, is being investigated.

(*g*) *Porphyrin and Haem Synthesis in Legume Root Nodules.*—Because of the direct correlation between the haemoglobin content of certain root nodules and their effectiveness in nitrogen fixation, haem and porphyrin biosynthesis are being studied in effective and ineffective nodules.

Ability to carry out various reactions in the biosynthetic pathway to protoporphyrin has been studied in homogenates of effective and ineffective nodules of soybeans, in nodule bacteria isolated from both types of nodules, and in cultured rhizobia of both strains (Wisconsin 505 and 507). All tissues, except nodule bacteria isolated from both types of nodules, appear able to convert δ-aminolaevulinic acid (ALA) to porphobilinogen (PBG). Protoporphyrin is synthesized when breis of effective nodules, but not ineffective nodules, are incubated with ALA. On addition to the ineffective nodule brei of a boiled extract of effective nodules, however, protoporphyrin synthesis occurs. In the ineffective nodule, porphyrin synthesis appears limited by lack of a heat-stable factor present in effective nodules.

(*h*) *Effect of Oxygen Tension on Hæm and Porphyrin Synthesis.*—Hæm and porphyrin biosynthesis *in vitro* are controlled by oxygen tension like cytochrome synthesis in living microorganisms. Synthesis increases to a maximum at oxygen tensions of about 0.05 atm, and then decreases at higher levels of oxygen. Most normal tissue oxygen tension levels are considerably higher than 0.05 atm. This may constitute an important control mechanism in animal and plant tissues as well as in microorganisms.

Using chicken erythrocyte preparations, it has been established that inhibition of oxygen tensions higher than 0.05 atm occurs later in the biosynthetic pathway than formation of porphobilinogen and earlier than formation of uroporphyrinogen.

11. BIOPHYSICS.

(Division of Plant Industry.)

(*a*) *Physico-chemical Studies of Tetrapyrrole Pigments.*—Investigations have continued on the physico-chemical behaviour of tetrapyrrole pigments from haemoglobin and chlorophyll, using the detergent solubilization technique. Three aspects have been studied:

(i) Relationship between basicity of a porphyrin determined in a detergent medium and its value in aqueous solution.

(ii) Determination of basic pK′ values and monocationic spectra (in aqueous detergent solutions) for a number of fully esterified porphins and chlorins.

(iii) Interaction between a porphyrin and a metal ion as typified by reaction between zinc and mesoporphyrin.

(*b*) *Membrane Studies in* Nitella.—Ion permeability and electrical properties of plant cell membranes are being studied. Comparison of two methods of measuring electric resistance of cell membranes confirmed the reliability of the microelectrode method. It has strengthened the conclusion that plasmalemma is the membrane of highest resistance in *Nitella*.

Further work on interaction between detergent cations and the *Nitella* cell wall indicated that activity of the " fixed carboxylate ions " within the cell wall (also the Donnan potential) can be evaluated from detergent uptake studies.

(*c*) *Measurement of Injury in Plant Tissues.*—The low frequency/high frequency resistance ratio method of determining injury has been further studied in relation to cold hardiness in lucerne for discriminating between plants with cells of different sizes, i.e. between diploids and tetraploids; resistance ratio is a less biased criterion of cold injury than low frequency measurements. For discriminating within an F_2 population derived from commercial strains, low-frequency resistance measurements are as satisfactory as resistance ratio determinations.

There is promise that the resistance ratio will be useful for studying drought injury, for which low-frequency resistance measurements are useless.

(*d*) *Translocation Studies.*—Translocation is being studied in relation to injury at the point of application of a herbicide.

(*e*) *Instrumentation.*—A portable microphotometer using photoconductive cells is being developed to cover the radiant flux range of 0.001 μW/sq. cm. to 0.1 W/sq. cm.

A system of measuring oxygen content of a gas over the region 0-100 p.p.m. with an accuracy of ± 1 p.p.m. is now in use. The system has an ultimate sensitivity of 1 part in 10^9. A modification is being considered for measurement of oxygen tension in soils.

A differential D.C. amplifier system is being developed for recording small temperature differences in the range of 0-2° C.

12. AGRICULTURAL PHYSICS.

(Division of Plant Industry.)

(*a*) *Soil Water Studies.*—(i) *General.*—Reviews on the physics of water movement in porous solids and the application of physics to problems of microhydrology were prepared at the request of the Highway Research Board of the United States National Research Council, and the International Union for the Conservation of National Resources.

(ii) *Effects of Field Heterogeneities.*—Vertical variations of soil conditions are likely to complicate interpretation of measurements of infiltration in the field. It has been established theoretically that heterogeneities may be present in the field which could not be inferred from infiltration observations *per se*. Curious aspects of some recent work in this field are thus explained.

(iii) *Absorption and Infiltration.*—Methods of analysis of viscous dissipation of energy during water movement in unsaturated media have been developed, and applied to problems of absorption and infiltration.

Analysis based on the momentum equation has resolved many difficulties which arise regarding the early stages of these phenomena. The Reynolds number of the motion at time zero is finite, and motion asymptotically (and rapidly) approaches that predicted by diffusion analysis.

(iv) *Temperature Effects on Soil Moisture Tension.*—Observed changes of soil moisture tension with temperature exceed those predicted by simple surface tension theory. This phenomenon, which is of importance both practically and theoretically, is being investigated. Experiments are well advanced and are yielding reproducible results in contrast to those of previous workers in this field. Parallel theoretical investigation, based on behaviour of trapped air in soil, promises to provide the required explanation of the phenomenon.

(*b*) *Micrometeorology.*—(i) *Theory of Local Advection.*—Conventional studies of micrometeorology, and such concepts as " potential evapotranspiration ", depend on the assumption of horizontal homogeneity at the Earth's surface. This assumption does not apply in a context of great interest in Australia—namely, in irrigated areas in arid regions. Quantitative analysis of such problems has been developed by solving atmospheric diffusion equations for heat and moisture, subject to appropriate conditions.

(ii) *Observations of Local Advection.*—A programme of observations has been designed to test the above theory. Sites have been chosen, and required micrometeorological equipment is being assembled and constructed.

(iii) *Analysis of Turbulent Boundary Layer.*—A formal mathematical framework has been developed to provide connected and consistent treatment of various gross features observed in boundary layers along smooth and rough plates with zero and non-zero pressure gradients. The formulation is equivalent to a mixing length hypothesis of novel type. Though the model cannot be exact, it approximates actual mixing processes sufficiently to form a useful basis for a gross physical theory.

(*c*) *Physics of Osmosis.*—Studies have led to improvements in understanding of plant water economy, in propagation of osmotic disturbances in cell aggregations, and in the mathematics of diffusion in plant tissue.

13. PLANT ECOLOGY.

(Division of Plant Industry.)

(*a*) *Rain-forest Ecology.*—Subtropical rain-forest is under study and its ecological relation to corresponding forests in southern Brazil. Field and laboratory experiments are in progress to analyse ecological factors controlling succession. Studies on regeneration of hoop pine (*Araucaria cunninghamii*) and silky oak (*Grevillea robusta*) are being continued. A specific biotic factor appears to be involved in the regeneration of *Grevillea robusta*.

(*b*) *Alpine Ecology.*—Permanent reference areas have been established to study the extent of soil and vegetation recovery following cessation of grazing at high altitudes. Small grazing trials support earlier conclusions that grazing has been selective and effectively very heavy. Evapotranspiration measurements indicate that at high altitudes dense *Eucalyptus* regrowth and shrubs are extravagant water users. Promising results in conversion of dense shrub growth to grass have been obtained by using hormone-like weed killers.

(*c*) *Ecology of Subalpine Grasslands.*—Studies of the origin of grasslands in subalpine areas have been completed. Investigations on modification by trees of their own microclimate are proceeding.

(*d*) *Ecological Studies of Southern Tablelands, New South Wales.*—(i) *Vegetation Survey.*—Delimitation and classification of plant communities have continued in the Yass River catchment. Data on natural and improved pastures in the area are being obtained.

(ii) *Distribution of Native Plant Communities in Relation to Soil Nutrient Status.*—The first phase of this work is complete. The level of exchangeable calcium in soil may have a bearing on the distribution of certain communities, and this hypothesis is being further tested. Where *Eucalyptus rossii* is a natural dominant, establishment of subterranean clover is unlikely to be successful in absence of lime.

(*e*) *Arid Zone Ecology.*—Investigations concerned with history of evolution of soils and landscape features in arid Australia have been continued. Present aridity is a recent development and wind erosion, a natural feature of the environment, is active, but has been accentuated by introduction of grazing animals and rabbits.

(*f*) *Effect of Root Temperature on Plant Growth.*—Earliest studies on microclimate in relation to topography revealed that major differences in soil temperature occurred on different aspects. This led to investigation of the effect of root temperature on the growth of subterranean clover. Differences in reaction to root temperature were observed in different strains of subterranean clover.

(g) *Growth Studies in* Eucalyptus.—Marked effects of gibberellic acid on the growth of *Eucalyptus* seedlings have been obtained, and anatomical effects of treatment are being examined. An attempt is being made to define dormancy conditions for *Eucalptus* spp.

(*h*) *Ecological Studies on Weeds.*—(i) *Distribution of Introduced Plants in South-eastern Australia.*—Comparison of the climatic range of introduced species in Australia and in overseas countries has been continued, with particular attention to weeds of Mediterranean origin. Effects of temperature and moisture status on germination of introduced species are being studied. Aqueous extracts of some seeds inhibit germination in others. The ecological importance of such inhibitors is being investigated in the field.

(ii) *Competition between Skeleton-weed and Pastures.*—Study at Cowra of the effect of competition by pastures on growth of skeleton-weed and the effect of the weed on succeeding cereal crops are nearing completion. Subterranean clover and Wimmera ryegrass reduced the population of skeleton-weed. Increased yield of wheat following pasture is attributed to increased soil nitrogen and reduction of skeleton-weed.

(iii) *Competition between Weeds and Pasture Species.*—Studies on the competitive effect of Wimmera ryegrass on hoary cress (*Cardaria draba*) have been completed, and suggest that ryegrass provides an effective competitor for this weed. Trials are in progress to determine how pasture species compete with certain weeds at different nutrient levels.

(iv) *Yass River Tussock* (Nasella trichotoma).—Investigations into control of Yass River tussock by competing pasture plants are being continued. Trials with various herbicides are under way to find one which can be used economically for treatment of dense stands of tussock prior to introduction of competing pasture species.

(v) *Bracken* (Pteridium esculentum).—Control of bracken in pasture is being investigated. Trials with various herbicides are in progress and will be followed by studies of the competitive effects of pasture plants.

(vi) *Control of Thistles in Pastures.*—Studies of the autecology of thistles have been continued. Control of variegated thistle (*Silybum marianum*) in pasture has been achieved with perennial species such as *Phalaris* and lucerne, but annuals are ineffective. Investigations into the the ecology and control of Scotch thistle (*Onopordum* spp.) have been commenced.

(vii) *Mintweed* (Salvia reflexa).—Investigations on control of mintweed have been commenced at Quirindi, New South Wales.

(viii) *Soursob* (Oxalis *spp.*).—Investigations on control of soursob have given promising results with the use of certain herbicides, and these will be further studied.

(ix) *The Control of Eucalypt Regeneration in Firebreaks.*—Effective control of *E. rossii* has been achieved with " Ammate ", 2,4,5-T, and a mixture of 2,4,5-T and 2,4-D. The effective of " Ammate " is enhanced by the use of a wetting agent. This work is being extended to other species of *Eucalyptus.*

14. FRUIT INVESTIGATIONS.

(Division of Plant Industry.)

(*a*) *At Hobart* (*Apples*).—The promise of previous experiments that cell division in fruits and thereby fruit size could be increased by spraying trees with certain growth substances has not been fulfilled. An increased number of cells in fruits was obtained by use of various substances in the first year of treatment. Treatment in subsequent seasons, however, was not so effective. In the case of naphthaleneacetic acid, cumulative harmful effects in one variety have occurred; fewer blossoms and fewer fruits, only slightly larger than those of control trees, gave a crop reduction of 60 per cent.

A new method of applying diphenylamine effective in preventing scald on apples during storage has been developed. This involves steam distillation and condensation and under certain conditions could be of practical value. The jet-scrubber previously described has been adapted to operate using water only, and a modification of the Eaves Dry Scrubber has performed very well in a commercial gas store. One of the most troublesome and expensive difficulties in operating a scrubbed gas store thus seems to have been overcome.

Comparison of internal carbon dioxide concentration in fruit of different varieties did not support the hypothesis that susceptibility to storage disorders is associated with internal gas composition.

Studies on the maturation of fruit in relation to climate, and mineral balance in relation to storage disorders and fruit size, have been continued.

(*b*) *At Applethorpe, Queensland* (*Apples*).—The main trials comparing performance of trees on different apple rootstocks are now in their twenty-first year. Little change in relative vigour and order of cropping of trees has been apparent during the past eight years. The heaviest crop of Granny Smith have been from trees on East Malling II. rootstock followed by Spy and E.M. XII.; the heaviest crop of Jonathan has been borne by trees on E.M. XII. stock, the next heaviest by trees on E.M. II. In other rootstock trials which are in their seventh and eighth years, differences are emerging in performance of trees on some of the newer Merton and Merton-Malling selected rootstocks.

Lightly pruned trees (Wickens method), though cropping poorly in the past five years, have borne average crops greater than hard (conventionally) pruned trees over twenty years of trial. Small plots of trees closely planted (10 feet by 4 feet) gave greater calculated yields per acre after eighteen years than trees at normal planting distances. In 1959, calculated yields per acre of Delicious were 678 bushels on E.M. XII. rootstock, and 600 bushels on English Crab. These yields exceed those on other plots at the Research Station planted at the usual 20 feet by 20 feet distance, and exceed usual yields per acre in the district.

It has been confirmed that sprays containing borax at 0.5 per cent. hasten fruit maturity. These sprays bring about an earlier conversion of starch to sugar in Granny Smith and Jonathan fruits.

Studies on development and maturation of the fruit of Granny Smith and Jonathan in relation to keeping quality have been continued; results on variation on cell numbers in fruits are almost complete.

15. TOBACCO INVESTIGATIONS.

(Division of Plant Industry.)

(*a*) *Canberra.*—(i) *Resistance to Blue Mould* (Peronospora tabacina).—*Genetics.*—Experiments on location and transfer of resistance to commercial varieties of tobacco are continuing. Resistance has been located in a single plant of the variety Virginia Gold, various Australian species of *Nicotiana,* and in *N. knightiana.* Resistance from the Virginia Gold spontaneous mutant appears to be determined by a single dominant gene with reduced penetrance. Resistance from *N. debneyi* when tested as seedlings, with heavy inoculation and high humidity conditions, appears to be determined by a single gene with low penetrance, or to be polygenic. In the field segregations suggest a single dominant gene.

A million seedlings raised from 2,150 seeds or pollen grains treated with mutagenic agents have been screened for resistance. Resistance previously reported, resulting from ultraviolet radiation of pollen grains, behaves like the natural mutant in the field and to artificial inoculation.

A further resistant line has been isolated from a seed treated with a chemical mutagen. No inheritance data are yet available for this line.

All of the resistant lines available are associated with undesirable characteristics rendering them unsuitable in their present form for commercial use. Plant breeding programmes have been initiated to produce commercial lines resistant to blue mould.

Stem infection.—Studies on the origin and course of the disease in the stem have been completed. Infection of the stem occurs by spread of fungus from the leaf via the vascular tissues. Stem infection in seedlings usually involves all tissues and death of the plants, but, when stem infection occurs late in the life of the plant, necrosis is usually confined to the periphery of the secondary xylem, the cambium, and the inner part of the external phloem. Incidence of stem necrosis is directly related to severity of leaf symptoms, and stems of plants infected early in development are generally brittle at the base. Mild stem infection, when plants are grown under conditions relatively unfavourable for development of the disease, promotes early flowering, modifies leaf shape, and reduces susceptibility to subsequent leaf infection. More serious effects of stem infection can be minimized by benzol treatment, high temperature, and low humidity, but the pathogen resumes growth and becomes destructive as conditions become favourable.

Effect of infection on growth and transpiration.—Evidence indicates that leaf growth practically ceases within 72 hours of inoculation irrespective of temperature conditions. Transpiration rate in diseased tissue is higher than in healthy tissue and the rate increases during the course of the disease until sporulation. The higher rate in diseased tissue is due almost entirely to increase at night-time. Following sporulation there is a significant drop in rate of transpiration.

Spore formation and dissemination.—Further studies on relation of temperature to spore formation confirmed and extended previous conclusions. It is now proposed to investigate the effect of light on sporulation *in vivo.* Temperature, humidity, leaf movement, and light all influence discharge of spores into the atmosphere. Rate of fall of humidity is particularly important—the more rapid the fall the greater the number of spores discharged.

Effect of microclimate on disease development.—Experiments are in progress to correlate blue mould development in the field with environmental factors shown by laboratory studies to be important in infection and in spore formation and dissemination. Temperature, relative humidity, and wind movement in terms of foliosphere measurements are being studied. Results of the first season's observations have been encouraging and work is continuing.

(ii) *Structure and Leaf Quality.*—Study of the relation between anatomical structure and " quality " in flue-cured tobacco leaves has been continued. The first aim has been to determine the structural basis of the various indices used by leaf appraisers in assessing leaf quality. A structural basis has been found for some indices. Other indices, such as " elasticity " and " lustre ", seem to measure attributes of chemical composition. The association of physical structures which render these attributes discernible by the leaf appraiser has not yet been defined.

(*b*) *Mareeba.*—(i) *Agronomy and Physiology.*—*Nitrogen studies:* Transformations of nitrogen in soil, and its uptake and metabolism by plants, are being studied in field trials by soil and plant sampling, and by soil incubation experiments in the laboratory. Total soil nitrogen changes little during the season, but nitrate nitrogen shows very marked fluctuations from a peak just before planting to a trough towards the end of the growing period. Effects of fertilizer on soil nitrogen are surprisingly small. Accumulation of nitrate and ammonium nitrogen in soils studied seems negligible below a depth of 1 foot.

Effects of halogens: A fertilizer trial was established in an area from which leaf with a high content of chloride had been reported in previous seasons. Effects of treatments on leaf quality and composition, and on soil, are being investigated. Uptake of bromine from the soil fumigant ethylene dibromide is also under study.

Manganese deficiency: A case of manganese deficiency has been indentified in the field, with symptoms closely resembling those of frenching. It could be corrected by a manganese sulphate spray. In view of the association of manganese nutrition with nitrogen metabolism, material from these manganese deficient plants is being analysed for free amino-acids.

Other nutritional studies: Investigations of interactions between the major nutrient elements, and of special effects of potassium on leaf quality, continue.

General agronomy: Varying delays were tried for the commencement of irrigation after planting. Early irrigation led to earlier infection with blue mould and earlier flowering; but yield was not affected unless irrigation was delayed 6 weeks.

The effect is under study of variation of date of planting on quality of cured leaf, and also the effect of planting gaps on plot yield.

(ii) *Plant Breeding.*—Breeding for improved yield and leaf quality under north Queensland conditions was continued. As a possible aid to this programme, components of yield capacity were analysed in commercial varieties, differences in leaf number and weight, among other components, being separted. Excluding disease losses, yields from existing varieties in Australia need not to be inferior to those from abroad.

Lines showing field resistance to blue mould (*Peronospora tabacina*) have been bred, resistance being derived from *Nicotiana debneyi, N. goodspeedii,* natural mutation, and mutation induced by ultraviolet irradiation. Inheritance of resistance from these various sources is being studied and compared.

(iii) *Biochemistry.*—Carbohydrates in tobacco leaf are being examined. Hot-water extraction of mature leaves after acidic hydrolysis yields galactose, glucose, arabinose, xylose, rhamnose, and an unknown sugar. Pectin constituents and hemicellulose removed by alkaline extraction are under investigation. Changes in sugar and starch content during leaf development is being studied. Starch present is being characterized for amylose-amylopectin ratio, and for the chain length and β-amylolysis limit of the amylopectin fraction.

Techniques are being developed for determination in leaf material of other constitutents which may be related to leaf quality.

16. PASTURE INVESTIGATIONS, CANBERRA.

(Division of Plant Industry.)

Considered in terms of total animal production efficiency of utilization of land resources in southern Australia is low. There are three major causes.

Inadequate soil fertility limits the use made of environmental factors of rainfall, temperature, and light in production of plant material. There is seasonal wastage of unconsumed plant material and a low degree of conversion into animal products of much consumed material.

Means of obtaining coincidence between quality and quantity of plant material and animal demand are being investigated, together with means of increasing efficiency within each of the limiting factors.

(*a*) *Agronomic and Soil Fertility Studies.*—In most of the higher rainfall areas subterranean clover and superphosphate have provided an effective means for raising the fertility status of soil. Changes in availability of soil nutrients are being followed to forecast and be prepared for occurrence of deficiencies of other nutrients which may become limiting. On the soils studied continued application of superphosphate for many years has not led to other nutrient deficiences.

The rate and nature of fertility build-up by clover and fertilizer is being studied, and methods devised for releasing this fertility for subsequent crops and pastures.

In some higher rainfall areas (e.g. parts of the wheat belt and coastal New South Wales) clovers have not been grown successfully. Inadequate soil phosphorus appears a major factor in this failure. Studies in wheat areas have shown that production has been continued under conditions of low phosphate and steadily declining nitrogen status. That average yields have not fallen under these conditions has been due to continual release of new varieties adapted to low fertility conditions, and having effective disease resistance.

In the lower rainfall areas of the wheat belt subterranean clover cannot be grown, and work has been concentrated on other legumes, particularly medics. Volunteer medics already exist in some areas but in many instances have undesirable characteristics. Burrs of many species have hooked spines, which are an objectionable feature in wool production. Hard seededness is an important disability. Much valuable nitrogen is immobilized, growing plant material is withheld from grazing animals, nitrogen is withheld from other pasture plants and crops, and fluctuations in production between seasons are wide and erratic.

Reduction of the proportion of hard seed produced is of major importance and methods for achieving this are being examined.

Medics are not highly successful on the grey and brown soils of heavy texture which constitute large and important wool-growing areas. Ecological studies are being made to investigate factors inhibiting the use of medics or replacement of present less desirable species with better selections.

Some species and strains can grow satisfactorily at nutrient levels too low to support other species or strains. By exploiting this characteristic it is hoped to reduce or obviate the necessity to provide these nutrients as fertilizers. Low carrying capacity, a direct result of erratic rainfall, demands that fertility build-up by legumes be attained at minimum cost for fertilizers.

Low winter production of pasture is a major limiting factor in the number of animals which can be supported and their production per head. This slow growth is due, at least in part, to decreased rate of release of soil nitrogen at low temperatures. Ability of various grasses to make optimum use of temporarily restricted nitrogen supply is being investigated.

Seasonal fluctuations in total and soluble nitrogen in surface soil of a *Phalaris*-subterranean clover pasture under two grazing treatments are being studied. Changes in soluble nitrogen following pasture renovation at different times of the year are also being investigated.

Winter spraying of a *Phalaris* pasture with gibberellic acid increases winter production, but does not increase total production. Gibberellic acid apparently has no adverse effect on the health of sheep, but no significant gain in liveweight was obtained. Further studies on the effect of gibberellic acid for increasing winter production are being made.

A number of perennial grasses have been compared with *Phalaris tuberosa* to test their ability to overcome seasonal deficiencies in *Phalaris* production. *Bromus inermis* has proved superior to *Phalaris* in production of green feed during the summer, and this has been reflected in greater wool yield on *Bromus* pastures than on *Phalaris*. For winter grazing a Mediterranean strain (C.P.I. 2145) of cocksfoot (*Dactylis glomerata*) was superior to *Phalaris* with respect to carryover of autumn green feed, available green feed throughout the winter, liveweight of sheep, and wool production. Further studies of these grasses for seasonal grazing on different topographic sites will be made at the new field station at Ginninderra.

(*b*) *Pasture Utilization.*—Interrelationships of plant and animal and factors of plant, animal, or plant-animal militating against high animal production per acre have been studied in long-term grazing trials reproducing valid property conditions. The causes are being studied of low consumption rates relative to amounts of plant material grown, and of low conversion of consumed plant material into animal products.

Even with present fertilizer techniques and pasture species animal production per unit area can be at least double that achieved by the more advanced livestock producers. This necessitates raising soil fertility to the optimum, provision for drought, and high animal numbers. This work has shown that many commonly held beliefs of desirable characteristics of pasture or pasture plant, and of many grazing practices, are erroneous. It has also indicated the future direction of plant and plant-animal investigations to define and correct factors limiting animal production.

Intake studies, to define the mechanism by which the animal obtains its food supply from pasture, the nature of the feed obtained, and its effect on the animal are being conducted in the field using oesophageal fistulated sheep and sheep in metabolism cages. This work involves studies of pasture changes, plant and animal factors governing grazing selection of certain plants or plant parts, the amount, composition, and digestibility of material consumed, the rate of passage through the animal, re-establishment of appetite, and the effect of variation in any or all of these on animal growth or on wool quantity and quality. Some of this work is done in collaboration with the School of Wool Technology, University of New South Wales.

There is variation in plant availability (both quantity and quality) throughout the year and the feed demand of the breeding animal also varies. The closer that periods of high demand can be made to coincide with those of high supply, and periods of low demand with those of low supply, the greater the benefit to the individual animal, the higher the number of animals which can be supported, and the greater the utilization of pasture.

Periods of high supply are commonly shorter than those of high demand by the ewe and lamb. To make use of the spring feed flush a high proportion of ewes are mated so as to lamb in spring. Early lambing is practised for the lamb to be as far advanced as possible when pasture deteriorates in summer.

This husbandry entails late pregnancy in winter when food is in short supply. Under a system of continuous grazing throughout pregnancy inadequate food supply was available in late pregnancy at high stocking rates, resulting in pregnancy toxæmia in ewes and high neonatal mortality in lambs. By restricting ewes to one-third of the area in early pregnancy and allowing them access to the other two-thirds in late pregnancy high stock numbers were carried. Losses from pregnancy toxæmia and lamb mortality were reduced and wool production per ewe increased.

17. PASTURE INVESTIGATIONS, ARMIDALE.

(Division of Plant Industry.)

(*a*) *Species Investigations.*—In a comparison of lucerne varieties, Du Puits and Caliverde slightly outyielded standard Hunter River. In another comparison a bred strain (Hunter River x *Medicago falcata*) outyielded Hunter River. Over a period of two years New Zealand grazing lucerne (*M. glutinosa*) proved more tolerant of wet soil conditions than Hunter River, but during a protracted wet period early in 1959 both species were killed out entirely. Applications of lime—2 tons limestone per acre worked into soil before sowing—gave an increase in yield of 23 per cent. Lime plus boron increased yield 42 per cent.

Rates of sowing of 5, 10, and 15 lb. per acre of Italian and short-rotation ryegrasses gave no yield differences. Nor was there any yield difference between species.

(*b*) *Pasture Management and Utilization.*—In a study of annual species to increase forage available in winter, giant rape and hungry gap kale far outyielded oats.

Utilization by grasses of nitrogen applied in different forms is being studied, with particular reference to winter response.

A large-scale experiment was sown to study methods of improving winter livestock production from pastures. The effect of different species, autumn resting, nitrogen fertilizing, and varying the stocking rates is to be investigated.

(*c*) *Improvement of Native Pastures.*—Progressive increase in yield of clover with increasing rates of superphosphate application has been obtained in a comparison of different rates of application of superphosphate to a surface-seeded native pasture. There has been a corresponding decrease in yields of native grass so that total yield from each treatment has remained about the same.

With prospective development of creeping strains of lucerne suited to Australian conditions and the likely value of these strains when surface seeded into native pastures, a study is being made of surface seeding of lucerne using the Hunter River variety. Lucerne established better than white clover, when sown either broadcast or with a combine.

(*d*) *Plant Nutrition Studies.*—In a comparison of superphosphate and rock phosphate as sources of phosphorus for pastures growing on a black earth soil it was found that in the first year only 5 lb. of superphosphate phosphorus per acre was required to produce the same yield increase as 160 lb. of rock phosphate phosphorus. In the second year 10 lb. of superphosphate phosphorus was required, and in the third year 17 lb.

Preliminary studies of the factors responsible for the failure of pastures on the western section of the Dorrigo plateau have been made. Applications of molybdenum and lime produce marked responses from a range of species. Phosphorus and sulphur are also deficient and responses to applications of potassium were obtained.

Studies of production of sulphate from organic matter in soils established the existence of specific intermediates in this transformation.

Following studies of the effect of varying the C/N, C/S, and C/P ratios on production of sulphate from pure organic compounds, further investigations have been undertaken of decomposition of plant materials in soils. Increasing the supply of either nitrogen or sulphur available to decomposing plant material resulted in higher levels of the other, although this was not as marked as in experiments using pure compounds.

(*e*) *Clover Nodulation.*—Lime and blood-bentonite pelleted seed of subterranean clover gave better nodulation than unpelleted seed, but nodulation was still not satisfactory. Blood-bentonite pellets proved no more effective than lime pellets. Further tests with pellets showed that even inert materials improved nodulation.

This suggested possible benefit from separating the inoculum from an inhibitory factor associated with the seed. Subsequent tests confirmed the presence of a substance associated with the seed which inhibits development of *Rhizobium*. Soaking subterranean clover seed in water reduced the inhibition effect.

18. PASTURE INVESTIGATIONS, DENILIQUIN.

(Division of Plant Industry.)

(*a*) *Semi-arid Pastures.*—To increase production of semi-arid pastures a grazing experiment has been established to assess the carrying capacity of varying proportions of saltbush (*Atriplex nummularia*) reintroduced into native pastures. The use of rooted layers from existing stands proved the most satisfactory establishment method for experimental work.

Dryland species trials have shown that summer dormancy is not a virtue in the semi-arid environment. It is interesting to note that none of the near-climax grasses exhibit summer dormancy.

Competition from weeds is important in establishment of dryland species and only *Phalaris tuberosa*, perennial veldt grass, *Dactylis glomerata* subsp. *hispanica*, and lucerne can survive if weeds grow in 42-in. spaced rows. Sowings of perennial grasses made without associated legume were all successful. There is little point in removing plant competition by cultivation and then replacing it with that of an aggressive legume plus superphosphate on soils low in nitrogen.

Lucerne, phalaris, and perennial veldt grass were established in 42-in. rows on Riverina clay and successfully oversummered where rows were treated with gypsum. Production has not equalled that on loam soils but successful establishment is an advance.

A trial to investigate use of fodder trees has been established, and Kurrajong, mulga, and boree are growing strongly.

(*b*) *Irrigated Pastures.*—Initial work on application of gypsum in irrigation water was done on Riverina clay. This has been repeated on Billabong clay with equally satisfactory results. Minimum concentrations of gypsum to give the desired effect have been determined and wide-scale tests throughout the region are planned for the next irrigation season. Trials to test long-term effects of gypsum treatment have been laid down and detailed measurements of structural changes commenced.

Equipment for field application studies is being developed in co-operation with the Chemical Engineering Section of the C.S.I.R.O. Designed as a prototype for commercial development it will allow determination of costs of treatment, and returns can then be assessed.

(*c*) *Species Testing.*—Trials, involving 36 pasture species, are being continued to test persistence. High winter production of ryegrasses (*Lolium* spp.) and the wide range of productivity of clovers tested are a feature of this work.

Superiority of a number of strains in the lucerne trial have been confirmed. Sixty lb. of seed of the Hairy Peruvian variety have been handed to the New South Wales Department of Agriculture for testing.

(*d*) *Soil Fertility Studies*.—The problem of poor nitrogen fixation has received attention. Under pot culture conditions Ladino strain is superior to other strains of white clover especially in summer, but all respond to applied nitrogen. Nutrients such as molybdenum, calcium, boron, and iron have no influence on nitrogen fixation on heavy soils of the area. On lighter soils satisfactory nodulation from native effective strains is usual but nodulation failed on Finley loam with both barrel medic (*Medicago tribuloides*) and subterranean clover (*Trifolium subterraneum*). Investigations of this problem have continued.

Long-term experiments were laid down to study accumulation of nitrogen in soils, and the first sampling is complete. Special reference will be made in this investigation to the supply of other soil nutrients and to the proportion of clover to grass. High losses of applied nitrogen were high-lighted in a previous grazing trial, and the residual effects of this trial were assessed with an oat crop. Substantial increases in yield were obtained on plots fertilized with nitrogen the previous year.

Nitrogen nutrition of rice in relation to flowing time and yield was investigated in a field trial. Flowering time and yield are interrelated and controlled by density of sowing and nitrogen. Competition between rice and a weed, *Echinochloa crus-galli,* for nitrogen, phosphorus, and sulphur was investigated in a pot trial. These results will have important implications in practice and further field trials are planned.

(*e*) *Time of Irrigation Studied*.—Early irrigation (beginning in February) gave spectacular increases in winter yield of subterranean clover-ryegrass pastures and time of first irrigation markedly influenced botanical composition. The effect of first irrigation time on carrying capacity is being assessed. This experiment, together with other irrigation work in progress, will provide the basis for investigations into efficiency of water use for pastoral production.

19. PASTURE INVESTIGATIONS, WESTERN AUSTRALIA.

(Division of Plant Industry.)

(*a*) *Studies of Perennial Grasses*.—(i) Phalaris tuberosa.—Studies at Kojonup elucidated reasons for the generally poor performance of this grass in the area. Failure is most acute on shallow soils of the slopes. Nitrogen deficiency, winter waterlogging, and restricted root growth combine to give low density and poor growth. Excessively high sowing rates result in final stand densities suboptimal for the environment. Nitrogen economy is greatly affected by waterlogging. Given ample nitrogen the grass produced almost as well in continuously waterlogged soil as in soil at field capacity. Tolerance to summer desiccation is being investigated. When moisture content of butt tissue falls below 50 per cent. (fresh-weight basis) tiller buds die.

Studies of the effect of soil depth on growth of *Phalaris* in association with Wimmera ryegrass have been commenced.

(ii) Hyparrhenia hirta.—This species was superior to annual type pasture at Perth over a three-year period. During summer, sheep body weights increase on *Hyparrhenia* and decrease on annual pasture. At the end of the summer difference in body weights of 20 lb. per sheep are usual. During winter, sheep performance was practically the same on both pastures.

Ten strains were selected from a collection of 140 for further testing of persistency, productivity, seasonal growth patterns, soil moisture utilization, and nitrogen content of herbage under intermittent defoliation.

Influence of water-table on growth will be examined since there is variation in depth to water in the Western Coastal Plain, the area of potential use of this species.

Comparison of several perennial species on five soil types at Kojonup has shown a marked effect of soil depth on nitrogen supply to the plant and the unsuitability of shallow soils of slopes for perennial grass culture. *Phalaris tuberosa* required a higher fertility level than cocksfoot or veldt grass. Both *Phalaris tuberosa* and veldt grass are more tolerant of water stress in summer than *P. coerulescens* and cocksfoot.

(*b*) *Species and Strain Experiments with Annuals*.—(i) *Subterranean Clover*.—A new extra early strain first discovered by Mr. A. R. C. Forrester at Carnamah has been studied intensively. Sown in early April this strain flowered 75 days from sowing and more than six weeks before Dwalganup. Difference in flowering time was reduced to ten days with mid-May sowing. Winter growth rate and factors influencing flowering are being studied in co-operation with the University Institute of Agriculture. Sward studies will be undertaken when sufficient seed is available.

There is now little doubt that long-term persistence is related to capacity for seed production in swards and that this is dependent on maturity grading. The relationships are not simple ones. Early mid-season strains which produce rather less seed per unit area than Dwalganup can persist satisfactorily in competition with it and can even prevent ingress of Dwalganup. In mixed swards of 50 strains early mid-season strains are outstanding by the fourth and fifth years.

This maturity group is now being studied intensively and comprehensive strain trials under continuous grazing are planned. Bacchus Marsh has again given better annual production than Dwalganup and Yarloop.

Defoliation markedly increases flower production and seed yield. Dwalganup outyielded Yarloop both in seed numbers and seed weight per unit area. Superiority was due to increases in the three yield components: number of racemes per unit area; number of burrs per raceme; and number of seeds per burr.

(ii) *Brome Grasses*.—Soft brome (*Bromus mollis*) has persisted well in competition with ripgut brome (*B. rigidus*). If after a further season this species still persists seed will be collected for examination of strain composition and probably for farm-scale testing.

(*c*) *Plant Nutrition Studies*.—(i) Extensive phosphate losses were noted from the top 4-in. layer of soil in experiments at Kojonup. Losses varied from 15 to 75 per cent. Losses could not be explained by plant uptake or animal removal, and, although some phosphate moves down the soil profile, amounts were insufficient to account for top soil losses. Broadcast superphosphate may be leached laterally out of the sandy top soil without opportunity for fixation in the impermeable clay subsoil.

In one deep sand at Perth, to which superphosphate has been applied to pasture for eighteen years, 80 per cent. of the phosphate has been lost from the top soil and 50 per cent. from the top 2 feet of soil.

Work will be extended to other soil types to examine the significance of leaching losses. This is the first occasion on which such extensive losses of phosphate by leaching have been reported.

(ii) *Zinc*.—Zinc deficiencies do not occur when the commercial superphosphate used contains 300 p.p.m. of the metal. The existence of zinc as an impurity in applied superphosphate may mask soil zinc deficiencies, which reappear when the impurity level falls. Lime has been used with commercial superphosphate to increase seedling establishment. Where level of zinc impurity in superphosphate was low, severe zinc deficiency occurred in clover, even when lime was applied at 400 lb. per acre.

(iii) *Chlorine.*—Severe chlorine deficiency was produced in subterranean clover grown in soil under glasshouse conditions. Extensive areas of soil low in chlorine have been found in Western Australia but no responses have been obtained in the field.

(iv) *Nitrogen.*—The extent to which annual pastures are limited by nitrogen supply is being studied at Kojonup. Several pastures varying in botanical composition and in proportion of clover have been treated with fertilizer nitrogen. Small responses were obtained even on clover pastures but responses up to 300 per cent. were obtained in pastures where legumes were not dominant. Responses were similar in winter and spring and resulted in increases in nitrogen content of mature herbage. These studies are being extended to include efficiency of nitrogen uptake, and rate and time of application in relation to winter leaching losses.

(*d*) *Ecology of Annual-Type Pastures.*—Studies of seasonal changes in botanical composition of annual pastures continued. No pasture deterioration in total production or botanical composition occurred in non-renovated pastures which received 40 cwt. of superphosphate over a period of ten years.

(*e*) *Soil Fertility Investigations.*—(i) *Effects of Phosphate.*—Yield of clover pasture at Kojonup increased consistently with phosphate applications but variable effects on soil nitrogen levels resulted between two sites. On one, there was a pronounced build-up; on the other, virtually no gain. Work commenced to clarify these discrepancies.

(ii) *Short-term Nitrogen Build-up in Clover Pastures.*—Wheat yield increase of 67 per cent. resulted from a single year under clover pasture before cropping, with, however, little effect on nitrogen content of the grain. This compares with 112 per cent. increase from five years under clover.

With wheat sown for the second consecutive season following clover pasture there was marked reduction in yield.

(iii) *Effect of Soil Type on Nitrogen Accumulation.*—On light soils clover remains dominant for several years and soil nitrogen increases regularly at rates of 40-80 lb. of nitogen per acre per year for the first four to five years. On heavier soils volunteer species tend to dominate the pastures after one or two years. At first nitrogen increases are very high (up to 300 lb. nitrogen per acre per year) but quickly falls to very low rates.

(iv) *Pasture Management.*—No differences in soil nitrogen build-up were found over a three-year period in a grazed clover pasture, a mown clover pasture from which herbage was removed, and a mown pasture in which herbage was dried and returned. Subsequent wheat crops have shown little variation in yield.

(v) *Urine-Nitrogen Losses.*—Losses of urea nitrogen in gaseous form are particularly substantial in summer. On Kojonup sand losses over eight-week periods were winter 28 per cent., spring 21 per cent., and summer 54 per cent. This work is being extended to other soil types.

(f) *Pasture Utilization.*—Past agronomic work in Western Australia concentrated on plant and soil studies and resulted in development of annual pastures suitable for the Kojonup area. Studies have now commenced of the most efficient utilization of these pastures. Work is confined to Merino sheep and experiments include all types of animals. Trials in progress are: stocking rate of clover pasture under continuous grazing by wethers at the rate of 1, 2, 3, 4, and 5 sheep per acre; weaner nutrition trials at three stocking rates (2, 3.5, and 5 sheep per acre) with and without a supplement of 0.5 lb. oats per day during summer; time of lambing and stocking rate trials involving three lambing times and three stocking rates (2, 3.5, and 5 ewes per acre).

20. PASTURE INVESTIGATIONS, QUEENSLAND.

(Division of Plant Industry.)

(*a*) *Agrostology.*—(i) *Spear Grass Region.*—*Rodd's Bay Experiment Centre*: Following the severe 1957 drought excellent growth was made by sown pasture based on the grasses *Chloris gayana, Paspalum scrobiculatum,* and *Paspalum plicatulum,* and the legumes *Phaseolus lathyroides* and *Centrosema pubescens*; native pastures oversown with *Stylosanthes sundaica* also recovered well. Stocking rates were between two and three-and-a-half times that of untreated native pasture, liveweight gains were between three and five times greater, and animals reached marketable conditions at three-and-a-half instead of four-and-a-half years.

Despite these improvements shortages of soil nitrogen are restricting grass yields well below the potential. In other experiments with pasture legumes, *Lotononis bainesii, Phaseolus atropurpureus,* and *Teramnus* spp. were outstanding.

By the third year all pastures included in grazing studies (except native pasture control) have received about 10 cwt. of superphosphate and 1½ cwt. of potassium chloride per acre. The effect of different rates and frequencies of application of these fetilizers on pasture establishment and growth is being investigated.

Brian Pastures.—Species within the genus *Stylosanthes* are the only legumes growing satisfactorily on granitic sandy soil. *Phaseolus lathyroides* is subject to severe nematode infestation in most years.

Samford Pasture Research Station.—Several recently introduced species of *Paspalum* have outyielded *Paspalum dilatatum* in a trial comparing yield and seasonal growth of 24 species and strains in the genus *Paspalum.*

An area of *Leucaena glauca* has been established for grazing management investigations.

(ii) *Wallum Country* (Beerwah Experiment Area).—Stocking densities of a beast to two acres were achieved on sown pasture mixtures at Beerwah; liveweight gains of 158 lb. per acre (316 lb./beast) are considered satisfactory.

The performance of four further sown pasture mixtures is being assessed under grazing. An experiment comparing tropical and temperate legumes with urea as sources of nitrogen in pastures under grazing has been commenced.

Sheep have been maintained continuously for over two years on a mixed pasture at an average stocking rate of 4.6 sheep/acre. In this period the stocking rate has varied according to pasture production fom 3.75 to 6.25 sheep/acre; both sheep and pasture are in good condition.

The South African legume *Lotononis bainesii* has shown excellent growth and ability to invade established swards; appreciable contribution of nitrogen to associated grasses was observed. Pangola grass (*Digitaria decumbens*) persisted for three years and has ability under moist conditions to develop swards carrying one beast per two acres in summer.

(iii) *Brigalow Region.*—*Regional field experiments.*—Pasture experiments have been established at "Havilah" near Collinsville supplementing those near Taroom and Goondiwindi; a coverage of soil and vegetation types representative of the full latitudinal extent of the brigalow country in Queensland has now been attained. *Sorghum almum* and buffel grass are thriving at all centres.

At Goondiwindi, *Panicum* species and *Phaseolus lathyroides* grew well. At Taroom Rhodes grass and *Urochloa* species and strains of *Phaseolus atropurpureus* and *Glycine javanica* were outstanding.

Grazing management.—Productivity and grazing management of *Sorghum almum* are being studied on fertile soil at the Cooper Laboratory, Lawes. Three different stocking intensities on plots of *S. almum* plus nitrogenous fertilizer, *S. almum* plus lucerne, and *S. almum* plus lucerne, *P. atropurpureus*, and *G. javanica* are being maintained.

(iv) *Plant Competition.*—Lucerne and *P. lathyroides* compete successfully for water with buffel grass and *P. scrobiculatum*, but grass growth improves later as a result of nitrogen contributions from legumes. Shading reduces legume growth only where water is not limiting.

(*b*) *Ecology—Spear Grass Region.*—Geological study of the area between Gympie and Gladstone, where the ecological pattern is directly related to distribution of geological units, is complete. Distribution of soils and plant communities in this area has been examined. Major components of this group of mesozoic geological units are shales of the Brooweena formation, siliceous sandstones of the Myrtle Creek formation, shales and sandstones of the Tiaro coal measures, and intrusive andesites and granites.

Study of 1,000 sq. miles of this region shows that soils are a mixture of podzolic, solodic, and lithosolic types carrying a variety of eucalypt forest and woodland. Within the major vegetal formations changes in plant species are closely related to soil type.

(c) *Legume Bacteriology.* (i) *Culture Collection and Supply.*—*Rhizobium* strains effective on nine *Trifolium* species native to the high mountains of Central Africa have been added to the culture collection. During the year 728 cultures representing 36 genera were supplied for use in field and glass-house experimental plantings. Nitrogen fixing ability of numerous *Rhizobium* strains on the following species was examined: *Desmodium uncinatum*, *Stylosanthes bojeri*, *Phaseolus atropurpureus*, and *Medicago tribuloides.*

(ii) *Calcium and Magnesium Nutrition of* Rhizobium.—Studies on calcium nutrition of *Rhizobium* in a chemically defined medium using potassium nitrate with biotin and thiamin instead of yeast extract, showed that depriving *Rhizbium* of calcium did not prevent growth. Calcium released magnesium into solution. Bacteria would not grow in a medium from which magnesium was omitted. Correlation between bacterial growth and degree of calcium saturation of colloid clays, formerly attributed to calcium, proved to be a response to displaced magnesium. Magnesium is an essential nutrient for *Rhizobium*, but needs for calcium is of a minor order and can be satisfied from impurities present in highly purified reagents. Therefore, a nodulation response to calcium is a plant response and not a bacterial response.

(*d*) *Pasture Evaluation and Animal Nutrition.* (i) *Nutritive Value Studies with Penned Sheep.*—Mature spear grass had a lower nutritional value than mature Rhodes grass, especially in autumn when sharply awned spear grass seeds reduced intake to low levels. *Paspalum plicatulum* showed higher nutritive value than most subtropical grasses, although there are marked strain differences within this species.

In late autumn digestibility and intake of *Urochloa pullulans* as cut hay and " standing hay " were the same, but the cut hay had a higher crude protein content. At the end of winter there was a marked fall in digestibility of " standing hay ", but intake and crude protein content were unaltered.

Comparison of nutritional values of strains of Rhodes grass has commenced and effects of nitrogen fertilizers on nutritional values of Rhodes grass are being assessed.

(ii) *Relationships between Chemical Composition and Nutritional Value.*—In experiments with subtropical pasture species it has been noted that crude protein is related to organic matter intake and digestibility in most species; crude protein content and crude protein digestibility are related; a highly significant relationship exists between crude protein content and succulence; in most species moisture content and digestibility and moisture content and intake are significantly related; crude fibre is not related to nutritional value except during the first few weeks of growth; and crude fibre is not related to either digestibility, intake, or crude protein content.

(iii) *Supplementary Feeding.*—*Phaseolus mungo* grain was used as a supplement to Rhodes grass pasture. In winter animals ate more dry Rhodes grass and gained more weight when supplemented, but when pasture was growing actively in summer there was no advantage in using protein rich supplement.

(*e*) *Plant Breeding and Genetics.* (i) Indigofera spicata (*Formerly* I. endecaphylla).—A small F_2 population raised from almost sterile crosses between biennial strains from Africa and a perennial strain from Ceylon showed a wide range of variation in morphological characters. An X_2 population gave a range of mutant types.

(ii) Leucaena glauca.—Selections for high dry matter and protein yields, branching habit, good seeding ability, and low mimosine content are being made within large F_2 populations from interstrain crosses. Studies of the genetics of selected characters in certain crosses have commenced.

(iii) Phaseolus atropurpureus.—Selections combining vigour, a stoloniferous habit, and good seeding ability were made from a cross between two Mexican strains. Populations of these selections growing in swards with Rhodes grass are assessed for persistence and vigour under grazing.

(iv) Lotononis bainesii.—This species is cleistogamous; therefore no natural variants are available. *L. bainesii* is particularly susceptible to the virus " legume little leaf "; mutants resistant to this virus are being sought in populations raised from seed irradiated with ^{60}Co.

(v). *Pulse Crops.*—High yielding strains of soybeans adapted to the fertile soils of the Darling Downs and brigalow areas have been isolated and selected. These strains will be tested in various districts and released to growers in co-operation with the Department of Agriculture and Stock.

(vi) Sorghum alum.—This grass is both self- and cross-pollinating and so considerable intra- and interstrain variation is present. Leafiness, degree of tillering, time of maturity, seed colour, sugar content, and cyanogenetic activity of different varieties have been assessed and a breeding programme to produce types suited to areas with 20-30 in. rainfall has been commenced.

(vii) *Rhodes Grass.*—Cytological and embryological work and observation of plant populations for strain variation in respect to yield, leafiness, time of flowering, stolon development, persistence, and frost tolerance is in progress.

(viii) *Apomixis.*—Apomixis in *Paspalum plicatulum*, *Paspalum urvillei*, and *Paspalum scrobiculatum* is being investigated to find means of inducing variation in apomictic grasses.

(ix). *Lucerne.*—A creeping-rooted lucerne variety for brigalow country is being sought, and crosses have been made between selected clones from Canadian creeping-rooted strains and strains adapted to lower latitudes from Australian, South American, and Indian sources. A low recovery of creeping rooted hybrids was obtained in F_1 and F_2 families and the majority of these are winter dormant. Creeping-rooted strains showing good winter growth have been selected and crossed.

(*f*) *Plant Chemistry—Nitrogen Compounds and Nitrogen Metobolism.*—(i) Leucaena glauca.—Feeding trials at the Cooper Laboratory and field observations have shown that *L. glauca* may produce toxic effects in ruminant animals. Investigation of the pharmacology of the active principle, mimosine, is therefore being undertaken. Paper chromatographic techniques used for mimosine determinations have shown that non-specific colorimetric methods usually used may give incorrect results when applied to animal metabolism studies.

Further work on separation and resolution of the diasterioisomeric 5-hydroxypipecolic acids have been carried out in collaboration with Dr. H. C. Beyerman, Technische Hogeschool, Delft. Analyses of his samples show that the original isolate from *L. glauca* had partially racemized during isolation.

(ii) Indigofera spicata.—Identification and determination in micro quantities of aliphatic nitro compounds in *I. spicata* and other *Indigofera* species has concluded. Some metabolism experiments were carried out using ^{14}C-labelled substrates.

(iii) *Analytical.*—Pastures grown at Beerwah in wallum country contain adequate cobalt to meet grazing animal requirements.

(*g*) *Plant Nutrition.* (i) *Regional Testing.*—Previous field experiment responses to phosphorus and calcium at Norwin on the Darling Downs were verified, and response to zinc has been obtained. Interrelationships of phosphorus, calcium, molybdenum, and boron on this soil are being measured.

(ii) *Mineral Composition and Deficiency Symptoms.*—Nutritional requirements of pasture species are being investigated with emphasis on potassium and calcium nutrition under glass-house conditions. Growth responses to phosphate were found to differ in pasture legumes under glass-house conditions and field experiments to confirm these differences have been laid down.

(iii) *Ion Uptake Studies.*—Radio isotopes of phosphorus are being used to measure phosphate uptake by plants with particular attention to comparative phosphate nutrition of pasture species.

(iv) *Nitrogenous Fertilizers.*—Application of ammonium sulphate to nitrogen deficient soils at the Samford Pasture Research Station has resulted in spectacular yield responses, accompanied by marked changes in botanical composition of the sward. During 1958 an application of urea to Rhodes grass pasture receiving adequate quantities of other plant nutrients gave a linear increase in dry matter production up to a rate of 400 lb. of elemental nirogen per acre per annum. Yields increased to 800 lb. nitrogen/acre, so increasing the rate of dry matter production from 3000 to 20,000 lb. per acre per annum.

(v) *Nitrogen Fixation by Pasture Legumes.*—Nitrogen fixing ability of the tropical legumes *Indigofera spicata, Desmodium uncinatum, Stylosanthes bojeri,* and *Lotononis bainesii* compared favourably with that of lucerne and Ladino white clover in sand culture. Direct transfer of nitrogen from legumes to grass grown in association is being measured.

(*h*) *Plant Physiology.*—Low temperature damage to pasture plants in inland regions of southern Queensland kills out some species and restricts growth in others. Investigation of the effects of low temperatures and light frosts on relevant physiological processes has commenced. Techniques for testing frost tolerance and growth responses at low temperature are being devised and correlation was confirmed between onset of lower winter temperatures and development of chlorosis in young shoots of tropical legumes; foliar chlorosis resulting from subjection to low temperatures in the species *Phaseolus atropurpureus, Centrosema pubescens,* and *Desmodium sandwicense* was similar in appearance to that caused by nitrogen deficiency.

21. FODDER CONSERVATION.

(Fodder Conservation Section.)

Throughout Australia rapidly increasing areas of improved pasture are calculated to increase stock carrying capacity. But the pasture available to stock varies from season to season and the pattern varies from year to year. If pastures are stocked only according to feed available at lean times, feed will be wasted at other times. Fodder conservation is the only practical way of saving this waste, and using it to increase the stock carried all the year round. Current haymaking and ensilage practices are often wasteful both in effort and materials. The Fodder Conservation Section's investigations are aimed to improve methods of conservation.

(*a*) *Haymaking.*—Investigations include field operations in haymaking and chemical, physiological, and physical changes which accompany curing of pasture material. Haymaking involves more than drying. Pasture material is living when harvested and respiration continues almost until the hay is dry enough for storage. Chemical changes occur during this period, and after dry hay is placed under cover a slow but progressive change continues for months or even years. These changes, resulting in loss of dry matter and reduction in nutritive value, are being studied and means sought for reducing them. Physiological changes also occur during curing and influence rate of drying. For example, stomatal closure usually begins within five minutes of cutting and is accompanied by rapid decrease in rate of moisture loss. The material becomes brittle and is difficult to handle without heavy losses. Study has been made of the effect of both growing and curing conditions on susceptibility to mechanical damage.

Studies have continued on crushing and laceration treatments for increasing the rate of curing of hay. Use of chemical desiccants is also being considered. Conditions under which treatments are most likely to find practical application have been defined. Field studies have been undertaken to reduce the cost of conventional haymaking.

(*b*) *Ensilage.*—Ensilage investigations are being carried out in experimental silos designed to permit control of variables involved in this biological process. Attention has been concentrated on the effect of maturity, moisture content, and temperature on conservation efficiency and silage quality. Changes in moisture affect not only losses of effluent but the whole course of bacterial activity. An optimum moisture content between 70 and 75 per cent. is indicated. Experiments with ryegrass/clover mixtures have shown that the presence of clover, even up to 50 per cent., does not result in less effective fermentation than with pure ryegrass, although effluent losses are increased substantially. It was confirmed that elevated temperatures counteract the beneficial effects of metabisulphite in making lucerne silage.

Growth of selected lactic acid bacteria in expressed ryegrass juice has been investigated further. Attempts were made to simulate substrate conditions resulting from wilting by freeze drying the juice, and diluting it. Wilting of ensilage prolongs the period for which bacteria (other than lactic acid producing types) remain prominent; all bacterial development is retarded at moisture levels below about 60 per cent.

Studies of nitrogen metabolism of ensilage have continued. Factors governing activity and stability of the proteolytic enzyme system in white clover have been investigated and this work is being extended to analogous enzymes in ryegrass. Attempts to limit post-harvest proteolysis in white clover by prior spraying with growth retarding chemicals have proved unsuccessful.

(*c*) *Chemistry of Fodder Conservation.*—Information is being obtained of the chemical composition of pastures and changes occurring during conservation, as a guide to nutritive value and efficiency of conservation. There is a need to develop new methods of analyses, since some current techniques are vague and inaccurate.

22. WHEAT RESEARCH.

(Wheat Research Unit.)

The Wheat Research Unit has been established with funds provided by the Wheat Industry Research Council to investigate factors affecting the quality of Australian wheat. The Unit has been attached to the Bread

Research Institute of Australia which is concerned with similar problems and has staff and equipment available for this work.

The Bread Research Institute is at present building new laboratories at North Ryde, Sydney, and is providing accommodation for the Wheat Research Unit. The entire Unit will be housed in the Bread Research Building.

Mr. Eric Bond, Director of the Institute, is also acting as Officer-in-Charge of the Unit. Mr. M. V. Tracey, formerly an officer of the United Kingdom Agricultural Research Council, has been appointed leader of the Unit. Other research appointments are being considered.

Quality problems associated with Australian wheat have been surveyed and a preliminary programme of research has been formulated.

IV. IRRIGATION.

1. General.

Irrigation on a large scale wherever it has been practised has usually brought, along with manifold benefits, deterioration in productive capacity of some of the land. Agricultural production in Australia continues to benefit from its expanding irrigation systems, but land is still deteriorating in certain areas owing to waterlogging and salinity. It has been questioned whether an irrigation agriculture can be permanent. The answer rests largely on the degree of protection that any specified area can be given by means of appropriate drainage.

The Organization has the Commonwealth Research Station (Murray Irrigation Areas) at Merbein, Victoria, and the Irrigation Research Station (Murrumbidgee Irrigation Areas) at Griffith, New South Wales, to study irrigation and drainage problems. Their work is reported in this Chapter.

Much of the work of the Division of Soils (see Chapter II.) has a direct bearing on irrigation. Irrigated pastures are studied specially at Deniliquin, New South Wales, by the Division of Plant Industry (see Chapter III., Section 18). Irrigation in northern areas is studied by the Division of Land Research and Regional Survey (see Chapter XI., Sections 6, 7, and 9). Conservation of water supplies for irrigation and other purposes by restriction of evaporation is investigated by the Chemical Research Laboratories (see Chapter XVII., Section 5). Work on dried vine fruits at the Commonwealth Research Station, Merbein, Victoria, is reported in Chapter XIII., Section 13.

Irrigation Research Stations.—Underground water and soil salinity continue as important research themes. Irrigation techniques applicable to dry land before development for irrigation have been examined. New lines of work are being developed on the use of solar radiation by the plant and its relation to the water regime.

For the first time, a meeting of the Executive Council of the International Commission on Irrigation and Drainage was held in Australia. Members visited the Merbein Station during their study tour. The Senior Officer-in-Charge, Irrigation Research Stations, is a member of the Australian Committee of the Commission.

The Officer-in-Charge, Griffith, served on the Blowering Dam Investigations Committee during the year.

The Commonwealth Dried Fruits Control Board, the Mildura Packers' Association, Co-operated Dried Fruit Sales Pty. Ltd., and the Nyah-Woorinen Enquiry Committee contributed again to Merbein Station Funds.

The Water Conservation and Irrigation Commission of New South Wales continues to contribute to Griffith Station funds.

Co-operation by the Departments of Agriculture in New South Wales, Victoria, and South Australia, the Water Conservation and Irrigation Commission of New South Wales, and the State Rivers and Water Supply Commission of Victoria is appreciated.

2. Merbein.

(*a*) *Irrigation and Reclamation.*—An irrigation timing experiment on sultanas last season gave significantly larger (9 per cent.) berries at harvest times from irrigation early in the roster, compared with late irrigation, for each watering during the growth period. This was not reflected in a significant difference in yield, owing to the complicating effects of a heat wave from January 11 to 22.

High usage of irrigation water in spring is an important practical problem in tile-drained areas. Co-operative investigations in Sunraysia have shown that infiltration from furrows over the drains may be greater than those remote from drains.

Further installations for periodical measurement of underground water levels have been placed in the Swan Hill and Kerang areas. Water-level measurements are used in determining aquifer properties and water movements. In these areas, additional information has been obtained on the hydraulic conductivity of the soils, including its variation with direction.

Hydraulic conductivity measurements, using screened auger holes, have been made at Renmark in areas with sandy subsoils. Such data, together with earlier findings on the shrouding of tile drains, have provided a basis for advice on tile drainage for reclamation of the types of land in question.

An electrical resistance analogue is being used to examine the effects of soil stratification and aquifer depth on the height of water-tables above drain level when drains are set at various depths below surface. Studies of this kind are helping to elucidate the problem of reclamation by drainage in the presence of shallow aquifers carrying water under pressure.

(*b*) *Viticulture.*—For the 1960 harvest a potential yield of 35-36 cwt. per acre of dried sultanas has been forecast. This is based on a finding in May of 58.2 per cent. potentially fruitful buds for the usual ten sites in Sunraysia.

Weekly examination of sultana buds from mid November bunch initiation to beginning of dormancy has shown that development of primordial shoots and bunches ceases about mid January.

For the potential fruitfulness of the sultana determined at dormancy each year for 15 years, a regression was established on hours of bright sunshine and maximum temperatures for the last fortnight of November (the period of bud initiation) and on minimum temperatures in the last fortnight of August (the period just before bud-burst).

This is being examined further to account more satisfactorily for the observed fruitfulness for 1959, a very late season.

To study the influence of sunshine on the developing bud, sultana vines were shaded from early November to early December by hessian, which reduced light intensity by approximately 75 per cent. At the end of the crop season the shaded buds showed reduced potential fruitfulness for the next crop.

Conditions during the dormant period for vines have been studied further. For the sultana there is no period for steady deep dormancy which suddenly changes to a state where only favourable temperatures are necessary for growth. The time required for buds to burst when placed in favourable conditions simply becomes progressively less during autumn and winter, the later the buds are taken. Moisture content of sultana buds was maximum in the third week in July, 1958, the same time as in 1957.

Examination of dormant sultana buds in May gave an average potential fruitfulness for the 1960 harvest of 58.2 per cent. This was based on 10 representative sites in Sunraysia which have been sampled year after year. In 1959, more bud examinations were made than ever before, including some from mid-Murray and South Australian areas. These confirmed the representative nature of the figures for Sunraysia. Previous indications that the percentage of fruitful buds for bud positions 4, 9, and 14 is similar to that for all positions were confirmed by examination of ten buds from each of these positions from each of 102 sites in Sunraysia. This gave an average potential fruitfulness of 59.0. A potential yield of 35-36 cwt. of dried sultanas for 1960 has been forecast on the basis of the bud examinations. Increasing use is being made of forecasts in the dried fruits industry.

A bud examination was made on sultana canes from properties affected by a hailstorm in November. Where crop losses due to the storm were higher than an estimated 80 per cent. only 30 per cent. of all buds examined were potentially fruitful for the next season. This and associated findings provided a basis for extension officers to advise on pruning of damaged vines.

Young currant vines sprayed at setting time with gibberellic acid at 20 p.p.m. yielded as well as cinctured vines and significantly better than vines sprayed with parachlorphenoxyacetic acid (PCPA) at 20 p.p.m. Untreated control vines gave only about half the crop of vines receiving the most favourable treatments. The increased yield with gibberellic acid appeared due to a large increase in berry size, while PCPA and cincturing promoted better setting.

An experiment to control the " bud strain " of the mite *Eriophyes vitis* in Ohanez vine buds showed that after fumigation of dormant buds for 16 hr. with either " Vapam " or " Nemagon " only dead mites could be found. Live mites were found after 24 hr. fumigation with ethylene dibromide.

(*c*) *Plant Nutrition.*—Long-established field fertilizer trials on sultanas are being continued. Yield in all plots is still high, but no important responses have been found.

In trials dealing with the rate of application of nitrogen to sultana vines, a yield increase from the applied nitrogen occurred only on one site, where the leaf nitrogen was previously low. However, no direct relation has been established between leaf nitrogen and yield.

Earlier work on the chloride and boron contents of sultana petioles and laminae has been supplemented by a study of these constituents in sultana berries grown on undrained Mallee soil.

A trial was begun in 1957 to compare the yields from cuttings from high-yielding and low-yielding sultana vines. Plants from both sources have so far made equal vegetative growth.

The nitrogen, phosphorus, and potassium requirements of sultana vines are being examined under sand- and pot-culture conditions. The effects of nitrogen deficiency were soon apparent in sand culture.

(*d*) *Vegetables.*—The Division of Plant Industry is co-operating in further studies of radiation-induced mutations. Tomato seed obtained after the treatment of pollen grains with X-rays and ultraviolet rays were sown in nematode-infested ground at Red Cliffs. The second generation was tested for recessive mutants showing nematode resistance.

Three tomato varieties resistant to root-knot nematodes and fusarium wilt (Merbein Early, Merbein Midseason, and Merbein Canner) were grown at Red Cliffs to provide mother seed. This seed, together with that of other resistant hybrids, was supplied to State Departments of Agriculture, seed merchants, and growers, for trials in various districts.

(*e*) *Cotton.*—Four varieties of cotton imported from the United States of America were grown under irrigation during the past two seasons at Merbein, Red Cliffs, and Coomealla. Three were medium staple varieties, and one long staple. Although there were losses of crop due to various factors including attack by native species of the rough bollworm, *Earias huegeli*, these varieties showed more promise than those tried in 1923.

(*f*) *Nematology.*—Established vines (Gordos, sultanas, Grenache, and Walthams) on six sites were fumigated with " Nemagon " at rates of 5 and 10 gal. per acre. Root and soil examinations suggested that citrus nematode and *Pratylenchus* have been eliminated by two successive treatments, but large numbers of root-knot nematodes survive treatment. *Pratylenchus* also appeared to survive when in a mixed population with the root-knot nematode.

Twenty-eight vine varieties propagated from cuttings in spring 1957 were planted in root-knot infested ground at Red Cliffs. In July, 1958, plants were root rated and transplanted to a new site. They were rated again in June, 1959, and discarded.

Five of these varieties were phylloxera-resistant stocks from the Research Station and four of them were appreciably more resistant to root-knot than *Vitis vinifera.* About a dozen rootlings of the most resistant stock have been worked to sultana scions for planting in the field next season.

(*g*) *Fruit Processing.*—The work of the Commonwealth Research Station, Merbein, on dried fruits is reported in Chapter XIII., Section 13.

3. GRIFFITH.

(*a*) *Soil Chemistry.*—In field experiments with citrus, losses of exchangeable potassium had previously proved smaller than those of exchangeable calcium. Laboratory tests showed that additions of high concentrations of sodium chloride and ammonium sulphate also resulted in a relatively smaller potassium than calcium ion release. It is thus not necessary to assume a release of potassium ions from primary minerals in a field experiment.

It is known that potassium nutrition of plants is often restricted when high concentrations of other ions are available. The relatively lower release of potassium compared to calcium could strengthen this limitation of potassium adsorption by plants. These conclusions could be applicable to the new irrigation area of Coleambally.

(*b*) *Soil Physics.* (i) *Land Drainage.*—Comparative measurements were completed of hydraulic conductivity made with the well-permeameter, piezometer, and auger hole methods. The well-permeameter method is of definite value in estimating drainage potential of dry land.

Measurements of frequency, intensity, and duration of peak flows from tile drainage systems were recorded on a numbers of farms as a check on the discharge rates. The highest peak flows so far recorded were after a 5-in. rainfall during March, 1959.

Leaching of soluble salts on a tile-drained part of the Research Station farm was studied during the whole year. The plot was kept bare of vegetation and did not receive irrigation water. Reclamation under these conditions was slow and depended entirely on infrequent, heavy rainfalls.

(ii) *Hydrology.*—A knowledge of ground-water conditions in dry areas outside the present irrigation schemes is important in planning future irrigation works. Piezometers were installed by jetting to depths up to 100 feet, but the nature of the sediments encountered made this method impracticable for larger-scale work. Further work will be done with drilling equipment. A general survey of ground-water in the Lower Lachlan-Murrumbidgee region was made by measuring water levels and piezometric pressure in existing wells and bores. This approach may produce a useful overall picture of the ground-water conditions.

(*c*) *Plant Physiology.* (i) *Plant-Water Relations.*—Work in the controlled environment room and glass-house has been expanded to include field studies of *Atriplex* species, to gain a quantitative assessment of the protein content of indigenous *Atriplex* species under field conditions of moisture stress, and of the degree of leaf shedding that occurs under these conditions. In the general programme on the effects of moisture stress on protein synthesis it is desired to determine how and to what extent the native saltbushes can maintain their content of leaf protein under harsh environmental conditions.

Seasonal changes are also being examined in the sodium, potassium, chlorine, nitrogen, and phosphorous content of field *Atriplex*, and in nucleic acid content. Studies are being augmented with glass-house cultures.

Studies of the lupin apex included nucleic acid synthesis and the effects of moisture stress on primordial initiation under controlled environment using selected varieties.

These moisture stress studies concentrate on those aspects indicated by previous work, e.g. the importance of young and embryonic tissues in resisting moisture stress, capacity to maintain protein levels in the face of stress, and the role of the phosphorus intermediaries in metabolism, especially of nucleic acid, both during and following stress.

To study cytoplasmic particles, such as mitochondria and microsomes, equipment has been obtained for the separation of such particles by high speed ultracentrifugation.

(ii) *Salinity Effects on Plant Growth.*—There is controversy over the reason for limited plant growth on salty soils. Some relate it mainly to decreased availability of water to the plant; others consider toxicity of adsorbed ions important.

Understanding of salt tolerance and salt sensitivity are important for the correct management of salty soils, the selection of species and varieties capable of satisfactory growth, and the development of diagnostic techniques.

Excess ion uptake is important in a number of barley varieties. Health of the plants was related to chloride and sodium uptake. The adverse effects on growth persist even after the plants have been transferred to a salt-free medium.

(iii) *Plant Nutrition—Peaches and Apricots.*—Analyses of leaf samples from commercial peach and apricot plantings were made to obtain nutritional data for long-term studies on drainage, salting, and mineral nutrient effects. The proportions of potassium, phosphorus, calcium, magnesium, sodium, and chlorine were obtained. The behaviour of rooted cuttings to varying " cold periods " was determined to plan experiments under controlled conditions outside the normal season, and to enable repetitive experiments to be carried out on plant behaviour to waterlogging conditions. To test the genetical variance 4000 rootstocks were budded for this work.

(iv) *Plant Nutrition—Citrus.*—The tilled treatment with farmyard manure of the factorial field experiment with citrus was substituted by a sub-clover treatment. The farmyard manure has shown no differences compared with the treatment without manure. As the usual winter crop of tick beans (*Vicia faba*) must be planted every year, it was decided to try the Yarloop strain of *Trifolium subterraneum*. This strain flowers sufficiently early to avoid undue competition with the trees in spring. An excellent clover sward was obtained in the first winter on the no-nitrogen plots, and on several of the lime plots.

The recovery of the sod treatment was continued with respect to yields and fruit quality, following the application of superphosphate since 1955. Even the very low yields of the no-nitrogen plots in the sod treatment have increased markedly, probably owing to the vigorous clover growth on these plots.

Study was concluded on the development of the Washington navel orange as affected by cultural treatments and levels of nitrogen supply. The object of this work was to establish critical stages in the development of fruit at which quality differences of mature fruit became apparent.

The earlier glass-house experiments were continued with soil sampled from the different nitrogen plots in the field experiment. A range of treatments was designed to improve growth and phosphorus uptake of citrus plants grown in soil selected from the high ammonium sulphate plots. These treatments included superphosphate at five levels, rock phosphate at two levels, silicate with and without superphosphate, a limed soil, and a fertilizer placement treatment. Best responses were obtained from liming, rock phosphate, and silicate with superphosphate, in decreasing order.

A glass-house experiment with navel cuttings grown in sand cultures was concluded successfully. These plants were grown at three nitrogen and phosphorus levels during the development of the fruit. The plants flowered and the fruit matured at approximately the same time as the orange trees in the field.

(*d*) *Entomology.*—Red scale (*Aonidiella aurantii*) can be killed on oranges by heat treatments varying from 50 to 70° C. No killing occurs in air temperatures of 35 and 40° C., but does occur at 45° C. with long time interval. Tests in a water bath at 1° C. intervals from 40 to 50° C., with an immersion time of 8 min., had no significant effect below 48° but gave 99 per cent. kill at 50° C. Tests on large trees covered by a tent suggest that it is possible to kill scale without damage to the tree but it is difficult to obtain adequate and uniform leaf temperatures.

(*e*) *Physics and Engineering.*—To relate solar intensity with transpiration and plant growth, it is necessary to develop suitable measuring equipment. Vacuum coating equipment has been installed and adequate spectrographic equipment will shortly be received, which will facilitate the design of apparatus to measure the back radiation of plants. This programme also includes the accurate measurement of water loss. Weighing systems have been developed of such a sensitivity that the major residual error is the change of buoyancy of the displaced air with change of temperature. On an inland station it is important that sufficient standards be maintained to ensure accuracy, and work is proceeding to create these facilities.

V. ANIMAL HEALTH AND PRODUCTION.

1. General.

Health and productivity of livestock are basic to the great national industries stemming from wool, meat, hides, and dairy products. Within the framework of the Organization's programmes of investigation, the Division of Animal Health and Production undertakes research for the animal industries, and undertakes investigation on the breeding, health, and husbandry of animals.

The headquarters of the Division is located in Melbourne, but its activities are spread throughout the Commonwealth. Reports on work in progress are presented in this Chapter and in Chapters VII. and VIII.

The work of the Division of Biochemistry and General Nutrition on nutritional problems is reported in Chapter VI. Section 12 of this chapter deals with investigations of the Animal Genetics Sections other than those on sheep and cattle which are included respectively in Chapter VII., Section 15, and Chapter VIII., Section 9.

Division of Animal Health and Production.—A process of decentralization of the Division has worked smoothly and progressively; local authority for research and administration has been delegated to officers in charge of principal units of the Division, and the Divisional Committee of Management deals with the broader issues of research and administrative policy.

The only major addition to the Division's research programme during the year was the establishment of a virology section at the Animal Health Research Laboratory, Melbourne. It is the first unit in Australia to be devoted specifically to research on virus diseases of animals, and it is expected to provide a training ground for workers in this increasingly important field. The range of research at the Sheep Biology Laboratory has been extended to include renal physiology which will facilitate studies on ovine posthitis and urinary calculi.

The Poultry Research Centre, in collaboration with the Animal Health Laboratory at Parkville, has commenced a programme of research on the biological basis of heterosis. Research on *Bos taurus* and *B. indicus* breeds and crosses of cattle at "Belmont", in relation to their ability to thrive in tropical environments, is being extended to include studies on comparatively haematology and response to nutritional stresses. Wool from breeding and selection experiments at "Gilruth Plains" is being processed by the Division of Textile Industry to determine whether a slight decrease in crimp number (without change in fibre diameter), which has accompanied significant increase in clean wool production, is of any consequence.

Eleven officers of the Division assisted universities with a course of lectures in their specialist fields and others gave single lectures. The subjects included genetics and animal breeding, chemistry, virology, parasitology, biology of the fleece, animal nutrition, histology, and microbiology.

The Division assisted in training eight visitors from overseas countries brought to Australia in 1958-59 on Fellowships under the Colombo Plan and the F.A.O. United Nations Technical Assistance Scheme. It also cooperated in programme planning for a further eight Fellows nominated to study in the coming year.

2. ANIMAL HEALTH RESEARCH LABORATORY, MELBOURNE.

(Division of Animal Health and Production.)

A section has been established to investigate diseases of livestock caused by viruses. This is the first special unit of its kind in Australia, and will help to meet an urgent requirement for a group to investigate important virus diseases already here and to strengthen defence against those which have not gained entry. Interesting results have already been obtained from study of important cattle diseases recently recognized for the first time in Australia (see Chapter VIII., Section 2). Research on contagious bovine pleuropneumonia (see Chapter VIII., Section 2) and on infertility in cattle (see Chapter VIII., Section 2) continue to represent a large and costly part of the Laboratory's programme; in both instances cattle are the only suitable susceptible hosts for reproduction of the disease. Good progress is being made in investigating hepatotoxic effects of pyrolizidine alkaloids and their derivatives obtained from plants (see Chapter V., Section 11).

Other major items of research included study of copper metabolism of sheep (see Chapter VII., Section 17) and of fertility and reproduction in sheep (see Chapter VII., Section 13). In concluding work on toxicity of large rations of wheat for sheep interesting and important observations were made on the haemodynamics of red blood cell storage in sheep (see Chapter VII., Section 12).

During the year Dr. A. W. Rodwell was invited by the New York Academy of Sciences to deliver a paper at a Conference on "The Biology of Pleuropneumonia-like Organisms" held in New York City.

The Officer-in-Charge, Dr. T. S. Gregory, and Dr. A. W. Turner were selected as members of a joint F.A.O./O.I.E./C.C.T.A Panel on the Control of Contagious Bovine Pleuropneumonia. The Officer-in-Charge was also invited to serve as a member of the W.H.O. Expert Advisory Panel on Brucellosis.

3. MCMASTER ANIMAL HEALTH LABORATORY, SYDNEY.

(Division of Animal Health and Production.)

A second dam has been built on the Parasitology Block of the F. D. McMaster Field Station, which will ensure adequate water supplies for irrigation for stock and improved pastures. Additional yards, pens, and sheds have been built which increase the value of the area for experimental purposes.

Training F.A.O. and Colombo Plan Fellows and courses for sheep and wool extension officers continue to tax available laboratory accommodation.

Three members of the research staff are at present undertaking post-graduate studies abroad, and the work of the laboratory will benefit on their return.

The Ian McMaster Fellows, Dr. E. J. L. Soulsby and Dr. I. W. Parnell, have concluded the tenure of their Fellowships. Their work has been of considerable assistance and an Ian McMaster Fellowship may be offered to another prominent overseas research worker.

The major investigations undertaken at the Laboratory are drought feeding, utilization of low-quality roughage, and vitamin A requirements in sheep (see Chapter VII., Section 11); heritability of fleece and mutton characteristics (see Chapter VII., Section 14); mycotic dermatitis, footrot, pregnancy toxaemia, carbon tetrachloride poisoning, and action of hepatotoxic alkaloids (see Chapter VII., Section 17); efficiency of anthelmintics, immunity to parasites, ex-sheathment of nematode larvae, epidemiology of parasites, and control of liver fluke (see Chapter VII., Section 18); life-cycles and control of external parasites of sheep (see Chapter VII., Section 19); and fattening of beef cattle (see Chapter VIII., Section 7).

4. VETERINARY PARASITOLOGY LABORATORY, YEERONGPILLY, QUEENSLAND.

(Division of Animal Health and Production.)

This Laboratory devotes the major part of its research to internal parasites and tick-borne disease of cattle. Other problems of importance to the livestock industry are studied as staff and facilities permit.

Accommodation and facilities are provided for officers of the Division of Entomology engaged on field and laboratory research on ecology and control of the cattle tick, *Boophilus microplus*. Facilities for field work for officers of both Divisions are available at Amberley Field Station, about 25 miles from the laboratory.

Facilities at Yeerongpilly were improved by erection of sixteen additional cattle pens for cattle tick work. All yards are gradually being placed under concrete, and the total area now covered is extensive.

A Memorandum of Understanding between the Department of Agriculture and Stock and C.S.I.R.O., relative to area of land and buildings made available to this Laboratory at Yeerongpilly, was completed during the year. The conditions agreed to by the Department were liberal and the agreement not only gives the Division security, but provides adequate land for expansion.

Improvement of Amberley Field Station continues as finance becomes available. Further clearing and logging have been carried out. A new set of calf yards was built and a cattle dip erected for acaricide trials. A second dip is under construction.

Mr. R. F. Riek was invited by F.A.O. to join a panel of F.A.O./O.I.E. experts on ticks and tick-borne diseases which met in London on November 24-29, 1958. Mr. Riek spent several weeks in Africa at Onderstepoort and Nairobi en route to familiarize himself with work done there on tick fevers.

Several Colombo Plan Fellows visited the laboratory during the year, and also two F.A.O. students.

Investigations in progress include studies on parasitic gastroenteritis of cattle (see Chapter VIII., Section 3), and on ticks and cattle fever (see Chapter VIII., Section 4).

5. F. D. McMaster Field Station, Badgery's Creek, New South Wales.

(Division of Animal Health and Production.)

Apart from a dry spring, seasonal conditions have been good. Water reserves for irrigation were not completely replenished but natural rainfall was adequate for improved pastures with little irrigation.

The milking shed has been extended from a two- to a three-unit plant, and a new machine installed. Bull yards and sheds have been increased to six, and a new cattle loading ramp built. A special crush was constructed to handle cattle for experimental purposes. An extensive eucalypt plantation has been planted to provide shade and a future timber reserve. Plantations have been established to shelter farm buildings and dwellings, and new irrigation areas fenced.

Major investigations on the Field Station are:—studies of inbred flocks of Australia Merinos (see Chapter VII., Section 14); inheritance of component fleece characters (see Chapter VII., Section 14); development of the Zebu-cross dairy herd (see Chapter VIII., Section 6); and coat shedding and sweat gland studies on cattle (see Chapter VIII., Section 6).

6. Sheep Biology Laboratory, Prospect, New South Wales.

(Division of Animal Health and Production.)

The research programme at this Laboratory aims to study aspects of physiology and ecology relating to productivity of sheep flocks. Work falls into several major categories: physiology of reproduction; endocrinology, morphogenesis, and genetics of wool growth; efficiency of wool growth; nutritional effects on fleece growth and quality; digestion and metabolism of sheep; climate physiology; and sheep ecology. During the year, work has commenced on renal physiology and attention will be focussed on urinary tract disorders. These studies are reported in Chapter VII., Sections 10, 13, 16, 17, and 22.

The isotope chemistry section is proving valuable to the general work of the Laboratory. Methods have been developed for separation and radioassay of labelled amino acids, for proportional gas-counting of $^{14}CO_2$, and for measurement of radioactive iodine (^{131}I) in thyroid glands of sheep and in blood cells of plasma. Apparatus was constructed for exposing organic compounds to tritium gas; this simple technique permits labelling of organic compounds with ^3H by means of radiation-induced exchange reactions, and has been used to label L-phenylalanine for studies of protein synthesis in sheep. Other work with isotopes is reported in Chapter VII.

A new service to State Departments of Agriculture has been initiated. Regular surveys are prepared of existing knowledge on sheep husbandry and these will be issued as a " Sheep Series " of the C.S.I.R.O. Liaison Notes.

The Fleece Analysis Laboratory undertakes measurement of fleece and cattle hair samples for research projects described in Chapters VII. and VIII.; a total of 32,700 measurements were made on wool samples, and 900 on cattle hair during the year. Efforts are being made to improve the accuracy of routine methods, especially wool fibre diameter measurement.

7. Regional Pastoral Laboratory, Armidale, New South Wales.

(Division of Animal Health and Production.)

The present research team consists of officers of the Divisions of Animal Health and Production, Plant Industry, and Mathematical Statistics. Accommodation is also provided for officers of the Wildlife Survey Section. Close liaison is maintained with the Faculty of Rural Science, University of New England, and several co-operative investigations commenced. Stock and facilities have been provided for field work for officers from the McMaster Animal Health Laboratory, the Sheep Biology Laboratory, the Wool Textile Research Laboratories, the Animal Breeding Section, and the Division of Plant Industry.

Soil-plant-animal relationships form the basic theme of the Laboratory's research programme. Studies of feed intake of grazing sheep and digestibility of pasture species have commenced and work on reaction of various grasses and clovers to grazing has been expanded.

At " Chiswick " an area of 2,370 acres has now been improved. A heartening feature was excellent recovery of so many sown pastures following very dry conditions over the spring and summer of 1957-58. Sheep shorn in 1958 totalled 6,086 and averaged 9.0 lb. of wool per head, including crutchings.

Investigations in progress by officers of the Division of Animal Health and Production include effect of nutrition on reproduction in sheep (see Chapter VII., Section 13); infertility on red clover pastures (see Chapter VII., Section 13); thyroxine and wool growth (see Chapter VII., Section 16); posthitis in wethers (see Chapter VII., Section 17); internal parasites (see Chapter VII., Section 18); feed intake and digestibility studies (see Chapter VII., Section 21); bloat (see Chapter VIII., Section 2); and drought feeding of cattle (see Chapter VIII., Section 7).

The Division of Plant Industry programme includes plant introduction, pasture ecology and autecology, plant nutrition, legume nodulation, pasture management, and utilization studies.

8. National Field Station, " Gilruth Plains ", Cunnamulla, Queensland.

(Division of Animal Health and Production.)

Drought which commenced in 1957 (rainfall 7.8 in.) continued throughout 1958 when only 9.9 in. of rain were recorded. The mean annual rainfall at " Gilruth Plains " for the 20 years 1938-57 was 15.8 in.

Less than 400 ewes were mated in 1958, the rest being left unmated to assist their survival under drought conditions. They came through well and following average rainfall in the early months of 1959 are now in good condition for mating.

Many perennial grass plants died during the drought, the species suffering most being *Dichanthium sericeum*, Queensland blue grass. Very few plants of this grass are still alive.

Sheep breeding experiments were temporarily interrupted, with the exception of the heredity x environment interaction experiment (see Chapter VII., Section 14). Work on polledness continued (see Chapter VII., Section 14), and study of conversion efficiency of feed to wool was intensified.

9. National Cattle Breeding Station, " Belmont ", Rockhampton, Queensland.

(Division of Animal Health and Production.)

Over the period April, 1958, to March, 1959, rainfall at Belmont was 35.56 in., some 3.5 in. below the mean. Apart from an almost rainless period from July to October, 1958, seasonal distribution was satisfactory for pasture growth. The winter of 1958 was very mild and the following summer relatively cool. Extensive flooding of the Fitzroy River occurred in February, and, although damage to fencing was severe, loss of pasture was negligible despite inundation for three weeks. Germination of Noogoora burr following this flood was extremely light due to competition of surviving grasses.

Quality and amount of pasturage available to stock during 1958-59 has probably not been equalled since the establishment of the Station in 1953. Weaning weights of calves, growth rates of young stock, and turnoff weights of mature animals all support this view. Recently established improved pastures are now making a significant contribution to available grazing. One river frontage paddock of natural pasture carried a beast to 1.3 acres from July to November and at no stage did the stock lose weight. Outlook for the 1959 winter is good.

Improvements completed during the year included a house for the resident veterinary officer and connexion of all buildings to city electric power supply. Pasture improvement continued; areas sown down in January, 1959, were opened for grazing six weeks later.

The Rockhampton Laboratory staff moved to new quarters in the former Commonwealth Health Laboratory building in January, 1959. This accommodation will provide improved facilities for cattle physiology studies associated with the " Belmont " programme.

The fifth calving of experimental groups on " Belmont " and the sixth series of matings were handled satisfactorily during the year (see Chapter VIII., Section 8).

10. Poultry Research Centre, Werribee, Victoria.

(Division of Animal Health and Production.)

The main breeding projects are long-range studies on population genetics, with emphasis on the mechanism underlying heterosis. This work is supplemented by physiological and biochemical investigations, and development of appropriate mathematical models; co-operation has been established with a biochemist at the Division's Animal Health Laboratory, Melbourne.

The laboratory was extended and climate control chambers constructed to house 200 layers in cages and several hundred chicks for growth experiments (see Section 11 of this Chapter).

During the 1958 breeding season a total of 1,102 dams was used and artificially inseminated with diluted semen obtained from 119 sires. Husbandry techniques remained unchanged except for replacement of the mash-scratch-grain feeding system by an all-mash diet of similar composition. General health of all stock was good and mortality rate was the lowest recorded at this centre.

Birds on the property at April, 1959, totalled 5,815 of which 4,429 were females of laying age, including 2,572 White Leghorn, 692 Australorps, and 1,165 crossbreds of various types.

At the request of the Victorian Department of Agriculture a sample of the unselected control flock and of the production bred M-flock of White Leghorns was entered in the Victorian Random Sample Test.

The Officer-in-Charge attended the 11th World's Poultry Congress in Mexico.

11. Investigations Other Than With Sheep And Cattle.

(Division of Animal Health and Production.)

(*a*) *Studies in Population Genetics* (Poultry Research Centre).—The following findings result from an analysis of egg production to 72 weeks of age of the 1958 hatched M-generation of pullets.

(i) The production-bred M-flock of White Leghorn, selected on an index combining individual and family performance, averaged 210.1 eggs. After ten years of selection, this flock produced 42.7 eggs more than the unselected control flock of the same origin. A detailed genetical analysis commenced of the M-flock.

(ii) Study of the use of three- or four-way incrosses by combining highly inbred strains of White Leghorn continued. Results confirm earlier conclusions that some strain combinations are more successful than others, but that even the best " nicking " combinations are not superior in egg production to the non-inbred and family selected M-flock of pure White Leghorn.

(iii) Single crosses between White Leghorn and Australorp representing the fourth generation of reciprocal recurrent selection, were, as in previous years, superior to the purebred M-flock in egg production of survivors, but they did not produce more eggs on the hen-housed basis on account of a higher mortality in the crossbreds. This higher mortality has occurred for several years, particularly in the cross of White Leghorn males with Australorp females (AxL), pointing to a maternal effect. The Australorp flock had in nearly all years a higher mortality rate than the M-flock of White Leghorn. This confirms the conclusion that, at least under cage conditions, the AxL cross is at least as economical as the popular reciprocal LxA cross.

The 11th and last generation produced by criss-crossing established with 225.4 eggs the highest egg production recorded up to 72 weeks of age at this Centre. This production level, obtained under normal field conditions, approaches closely the average results for crossbreds obtained at the ninth Californian Random Sample Tests.

(iv) Study of the effect of selection in a crossbred population continued in an F_4 generation. This method is not superior to either between-breed crosses or family selection within a purebred flock.

(v) The Australorp flock bred for a few years by selection methods similar to the production-bred White Leghorn M-flock has responded very slowly with respect to improved production.

(*b*) *Avian Physiology and Nutrition* (Poultry Research Centre).—The physiological basis of heterosis is under investigation. Birds of purebred strains of White Leghorn and Australorp and their reciprocal crosses have been used. Growth response to some dietary-essential amino acids have been investigated. Results indicate breed differences and heterotic effects for essential amino acids.

(*c*) *Plant Poison Studies with Plants Containing Pyrrolizidine Alkaloids* (Animal Health Laboratory, Melbourne).—Investigations with major alkaloids of the plant *Heliotropium europaeum* have been directed to (a) elucidating in greater detail the nature of the biochemical lesions resulting in enlargement of liver cells and their nuclei and (b) examination of conditions under which the disease will progress to a fatality. The rat has been used in most of these studies but a strain of mice with a hereditary defect producing dwarfs was imported for the study of some aspects. Pharmacological studies have been intensified and directed towards differentiating those alkaloid effects causing death from those producing chronic liver lesions.

Chemical methods for quantitative determination of micro amounts of alkaloids in animal tissues have been developed and can now be used to trace alkaloids in the animal. Survey continues of the pathological effects of total alkaloid extracts of plants belonging to the same family as *H. europaeum*, but no new hepatotoxic plant has been found.

(*d*) *Trace Element Studies in Western Australia.*—Assistance was provided to the Department of Agriculture in assessing cobalt and copper status of livestock and pastures on which they graze. An accepted method for cobalt analysis has been modified and its accuracy improved. As a contribution to the study of copper deficiency diseases in ruminants, the levels of copper, molybdenum, and inorganic sulphate in some Western Australian pastures have been determined.

(*e*) *Comparative Biochemistry of Copper.*—Earlier work at the Department of Agriculture, Perth, suggested that fowl and duck might differ greatly with regard to control of copper storage. This has not been confirmed by further experiments; both species were able to limit storage when fed moderate amounts of additional copper. Useful information regarding routes of excretion was obtained. Assistance has been given with the work of the Zoology Department of the University of Western Australia on the copper and cobalt metabolism of the marsupial.

(*f*) *Physiology of Reproduction* (Sheep Biology Laboratory, Prospect).—Many fertility phenomena can be conveniently and economically studied with mice as experimental animals. Recent observations on mice have been concerned with the action of gonadotrophins on the ovary, effect of pituitary gland extracts on growth rate of inbred mice, dynamics of sperm penetration of eggs, and relation of serum beta-globulin in prenatal mortality.

12. ANIMAL GENETICS.

(Animal Genetics Section.)

The Animal Genetics Section investigates application of genetics to animal breeding and allied fields, and trains students in this subject.

One Ph.D. student has completed his training and also one honours student. Three students are studying for the Ph.D. degree. One Fulbright post-graduate student, Mr. R. Klay, has been working in the Section. A genetics course has been given to third year Zoology students by Dr. Grigg and Mr. Sheldon. The electron microscope bought in collaboration with the Division of Food Preservation and Transport is now being installed.

During a visit to the United States, Dr. Sobey studied work in progress on the nature and culture of viruses. It is now generally believed that viruses can infect with the DNA fraction by itself. Myxoma virus is being cultured and subjected to selection at Davies. Tissue culture is being widely used as a medium for growing virus and techniques seen in operation in the United States are being tried.

(*a*) *Genes and Chromosomes and Other Granules.*—No electron microscope work has been possible this year as no microscope was available in Sydney. A mass of material awaits examination. In the meantime other lines of work on the synthesis of cell contents have continued. Electron microscope examination of cells last year indicated that cytoplasmic nucleic acid is manufactured in the nucleus and passed out into the cytoplasm. If this is so, inhibition of synthesis should result in a fall of nucleic acid in the cytoplasm. This has been confirmed as follows. When cells are treated with ribonuclease their cytoplasmic nucleic acid is destroyed and they die. Nucleic acid content can be restored and the life of the cell saved by treating the depleted cells with foreign nucleic acid; if thiouracil, which inhibits nuclear synthesis of ribonucleic acid, is included in the treatment, no restoration takes place. Restoration thus operates by restarting synthesis in the nucleus and not through direct replacement with nucleic acid of foreign origin. Radiation is another agent which interferes with nucleic acid synthesis, and experiments have begun on irradiated mice, to study radiation damage and how it can be repaired. So far the most interesting observation is localization of radiation damage in mouse gut where it is almost completely confined in its gross observable form to the epithelium of the jejunum and duodenum. This work, which will be paralleled by morphological studies under the electron microscope, is designed to explore relationships between viruses, antibodies, and cell synthesis, including chromosome duplication on one hand, and cell structure and activity on the other.

The possibility that genes can mutate not only from the normal to a mutant type, but also back from the mutant to the normal is an important point to decide. This has a direct bearing on the type of gene change on which both natural and artificial selection rely. Back mutation has been reported, but frequently cases supposed to be back mutations have turned out not to be so, and to have other explanations. For theoretical reasons it would be premature to discuss in detail, it is supposed that back mutation may occur as a result of unequal intragene sister-strand crossing over. In this case back mutants should reveal incomplete reversion to type following a definite pattern. *Neurospora* stocks were tested for back mutation and eighteen partial back mutants were found. The back mutants were phenotypically similar to wild type until exposed to unusual temperatures, when differences between them were revealed. Work on other mutants continued to include them in the same investigation.

During the past three years the effect of gene changes on variability has been investigated in *Drosophila* and mice. Both investigations reveal a similar pattern. Characters normally showing little or no variation do so because in their normal phenotypic range they are buffered against influences, both genetic and environmental, which tend to shift the phenotype from its normal course of development. In the mouse experiment the introduction of the gene tabby caused reduction in the number of certain vibrissae from 19 to about 10; but whereas the number 19 in normal mice was almost invariable, the number 10 was highly variable. When future parents were chosen for their extreme vibrissa number from tabby mice, lines with high and low numbers were produced, showing that variation was genetic. Wild-type mice carrying the normal instead of the tabby gene segregated in selection lines, and, although all selection was based on the phenotype of tabby mice, after a few generations wild-type mice began to appear with abnormal numbers of vibrissae. Genetic variation is present in the wild-type mice with 19 vibrissae but is not expressed. The mechanism of suppression is not yet clear. In *Drosophila* an experiment of similar design using the scute gene which reduces scutellar bristles from four to about one and a half has had much the same result. In addition, selection for invariability has resulted in a mean phenotype which is very stable. When stocks which have been selected for lack of variation about a mean of two bristles are subjected to unusual temperatures during development, they are much less affected than unselected stocks. A scale has been worked out in *Drosophila* showing the relative sensitivity of flies during development depending on their potential phenotype. At a phenotype of one, two, or three bristles it takes about one unit of genetic change to increase the mean by one bristle. It takes eight times this change if the mean phenotype is four bristles. Five, six, and seven bristle phenotypes appear as sensitive as one, two, or three bristle phenotypes. The experiment has a bearing on the explanation of dominance. The first gene substitution of a ± gene for an *Sc* gene in *Sc Sc* flies has an effect of gene dose of about seven units; the second gene substitution has the effect of about one unit. Thus there is dominance on any scale, but, whereas one gene substitution keeps all flies well inside the four bristle zone in normal stocks, in the selected stocks this is not so and the gene appears incompletely dominant once the phenotype is pulled sufficiently far from its normal range. The two sets of experiments suggest that a reorientation of view towards the effect of selection on populations and their variability is required. Several experiments were initiated in the mouse colony to explore the nature of the fringes of canalized zones and to disentangle the conservative effects of canalization and linkage on fitness.

Long-term selection experiments continued in *Drosophila melanogaster* on two typical quantitative characters. The characteristics being studied here are the number of bristles on the abdominal segments and the body weight.

The bristle selection lines have been in progress now for over 50 generations and three out of the four have been at a standstill for 20 odd generations, but one low line continues to make slow progress. This line had a big increase in frequency of a single recessive gene, causing sterility when homozygous, from the 13th to the 33rd generations, and the response slowed down during this period. In recent generations the detectable frequency of this gene decreased, for unexplained reasons. Large differences in response to selection were found between replicates, especially in the high lines, confirming and amplifying conclusions of other workers in this field, that current animal breeding theory has much less useful predictive value than previously thought.

Extent and period of response in the body weight selection programme were smaller than in the bristle selection programme. However, differences between replicates were small, and during the short period of response, low lines responded at much the same rate as high lines. Gains made, however, were substantially retained during the subsequent 20 generations when no selection was done. Analysis of these lines is not complete but predictions based on animal breeding theory appear to have been more closely followed in practice by body weight lines than bristle lines.

(*b*) *Myxomatosis*.—The number of rabbits available for testing for resistance to myxoma virus and selection has increased annually, and in the first five months of this year 600 rabbits were tested. Response to selection is steady. Percentage recovery increases by about 3.8 per cent. per grade, where a grade approximates one generation. Grade 3 rabbits have a 20 per cent. recovery. No wild rabbits have been tested. It has been noted that as in the wild state, wild rabbits in the outdoor enclosure breed most readily in winter, whereas this is a poor breeding season for the cage rabbits unless given supplementary lighting.

Attempts have been made to alter myxoma virus by introducing chemical analogues into infected animals. Encouraging preliminary results have not proved repeatable. This work is continuing. Facilities for growing the virus in tissue culture are now available and various forms of selection in this medium are planned. A satisfactory method of measuring antibody response to myxoma virus has not yet been achieved.

(*c*) *Serology*.—Data have been collected on inheritance of antibody response to various antigens and correlations between these responses.

Chemicals known to affect protein synthesis in microorganisms have been tested for their effect on antibody response. Under the conditions of testing neither thiouracil nor ribonuclease affect antibody response significantly. Chloramphinical increases antibody response.

Inheritance of anaphylactic sensitivity was measured and found to be high. Selection for lines of mice with high and low sensitivity is now in progress.

Attempts to correlate anaphylaxis with mast cell function have proved fruitless. Severe reduction of the mast cell population by heavy dosing with "48/80" has no effect on anaphylactic shock; conversely no difference in mast cell distribution has been found in mice killed by anaphylaxis.

Detailed quantitative studies of antigen/antibody ratios with respect to anaphylaxis have been delayed by inability to produce ascites antibodies in mice. This has been accomplished after importation of complete adjuvant from the United States.

(*d*) *Mice*.—The work on histo-compatibilities originating in inbred lines of mice progressed satisfactorily. Two such differences were discovered.

A large-scale experiment on induction of phenocopies and mosaics by radiation during foetal development is in progress. White areas of coat, diagnosed as gene mutations by the Russells of Oak Ridge, are probably cytoplasmic rather than nucleogenic mutations.

(*e*) *Genetics of Sheep*.—The work of the Animal Genetics Section on the genetics of sheep is reported in Chapter VII., Section 15.

(*f*) *Sweat Glands in Cattle*.—The work of the Animal Genetics Section on cattle and skin is reported in Chapter VIII., Section 9.

(*g*) *SILLIAC*.—Use of electronic computers for theoretical analyses of the effects of selection on genetic systems has been continued and expanded, producing interesting results in the fields of linkage and epistasis.

VI. NUTRITION.

1. General.

Because of its very extensive pasture areas Australia has a specific interest in the nutritional processes of the ruminant animal. Although sheep and cattle hold a basic importance to the well-being of mankind, until quite recently only a meagre fund of exact knowledge has been available on ruminant physiology and the nutritional factors governing the conversion of pasture plants into useful animal products.

The Division of Biochemistry and General Nutrition is active in this field; it has concerned itself mostly with study of the wool sheep. Many applications arising from its investigations have increased the overall efficiency of sheep husbandry, and provided a sounder basis for maintaining flocks. Studies of trace element deficiencies have lead to the solution of agricultural problems of considerable economic significance, and have stimulated the delineation of areas in every State where agricultural development has been limited by trace element deficiencies.

The current investigations of the Division are described in this Chapter, in Chapter III., Section 8, and in Chapter VII., Sections 2-9.

Other investigations bearing on animal nutrition are undertaken in the Division of Animal Health and Production (see Chapters V., VII., and VIII.) and the Division of Plant Industry (see Chapter III.).

Division of Biochemistry and General Nutrition.—The research programme of the Division has continued without major alteration. Many of the Division's investigations on sheep nutrition are applicable not only to wool production but also to the meat industry. Research has now been extended into this latter field.

Investigations have continued at the Division's Field Stations. At Glenthorne, experiments are conducted on salt tolerance, cobalt pellets, &c. The facilities for pen-feeding experiments there are being increased. At Robe, a number of experiments are in progress to extend knowledge of how best to deal with cobalt and copper deficiencies under conditions of station practice, and a series of trials of the relative efficiencies with which various types of heavy, cobalt-containing pellets protect flocks from the demyelinating disease, phalaris staggers, is being carried out at other sites in the south-east of South Australia.

2. Nutrition and Wool Production.

(Division of Biochemistry and General Nutrition.)

Experiments are progressing to extend information of efficiency of utilization of protein by high-producing Merino sheep. Rates of nitrogen turnover are being estimated by introduction the isotope ^{15}N into experimental animals. To make full use of the isotope the experiments have been designed to investigate, in addition, aspects of energy metabolism.

3. METABOLIC PROCESSES OF SHEEP.

(Division of Biochemistry and General Nutrition.)

Study continues on the metabolic processes through which ruminants deal with matter and energy. *In vivo* and *in vitro* studies of the metabolism of propionic acid are being pursued. It is now clear that a failure to metabolize this fatty acid with normal efficiency is the most serious disability suffered by cobalt-deficient ruminants. Vitamin B_{12} is an important part of an enzyme, propionyl conezyme A isomerase, responsible for one of the links in the chain of biochemical transformations that prepare propionic acid for use as an energy source in animal tissues. Processes are being studied which are responsible for the metabolism of certain amino acids which fail in vitamin B_{12} deficiency and which become seriously impaired as a result of folic acid deficiency. Individual researches on some of the problems are referred to briefly in Chapter VII.

4. ENERGY METABOLISM OF SHEEP.

(Division of Biochemistry and General Nutrition.)

Studies have been continued of the overall thermodynamics of food utilization. The main experiments in this field at present in progress seek to determine the source of extra energy dissipated by sheep after consumption of protein. Although the phenomenon has been observed in all higher animals, little is known of the metabolic reasons for this loss of energy. These experiments are described briefly in Chapter VII., Section 4.

5. MICROBIOLOGICAL PROCESSES OF RUMINATION.

(Division of Biochemistry and General Nutrition.)

Studies have been further extended of the transformations, degradations, and syntheses effected by microbiological agents within the rumen. Some of these activities are referred to in Chapter VII., Section 3.

6. SALT TOLERANCE OF SHEEP AND STOCK WATER POTABILITY.

(Division of Biochemistry and General Nutrition.)

The second series of the experiments on the potability of saline waters has been completed, and work has commenced on the toxicity of magnesium salts.

A brief account of the findings is reported in Chapter VII., Section 9.

7. CARBOHYDRATES AND STEREOCHEMISTRY.

(Division of Biochemistry and General Nutrition.)

In the field of the stereochemistry of carbohydrates, research on the interpretation of functional aspects of carbohydrates in living processes have been continued.

Studies of the ionophoretic behaviour of carbohydrates and related compounds have been extended by employing uranium salts as electrolytes.

The value of sodium arsenite as an electrolyte for paper ionophoresis of carbohydrates has been greatly increased by discovery of two effective methods of detecting non-reducing carbohydrates on paper in the presence of this salt.

Ionophoresis of heavy metals in electrolytes containing carbohydrates was investigated and abandoned as having little promise as an analytical tool.

It was found that carbamates (i.e. *N*-carboxy-derivatives, $R.NH.CO_2^-$) usually formed when amino compounds are dissolved in alkali are easily detected by paper ionophoresis. Carbamates were found to be readily produced from all amines and amino acids containing a primary amino group, except those of the *tert*.-butylamine type such as α-amino*iso*butyric acid. These studies provided means of measuring by ionophoresis the number of functional, reactive, amino groups in complex molecules.

8. MINOR ELEMENT DEFICIENCIES IN ANIMALS.

(Division of Biochemistry and General Nutrition.)

Research continued to reveal the nutritional significance of minute traces of zinc, copper, cobalt, &c. Studies in this series that concern the welfare of grazing animals are reported elsewhere (see Chapter VII.) and those that concern pasture development are mentioned in Chapter III., Section 8.

Investigations are complete on the influence of zinc deficiency on protein turnover in the rat. The first series of experiments to determine the nature of the mechanism through which copper influences the physiological process of keratinization is nearing completion. Determinations are being made of the amino acid constitution of samples of wool keratin grown under well-controlled conditions of copper deficiency.

The roles of vitamin B_{12} and of folic acid in the intermediary metabolism of volatile fatty acids are being investigated both in ruminants and in rats.

9. VITAMIN B_{12} AND FOLIC ACID.

(Division of Biochemistry and General Nutrition.)

Current investigations have thrown light on the physiological mechanisms in which both vitamin B_{12} and folic acid play essential roles.

Special attention has been given to the part played by vitamin B_{12} in the metabolism of propionic acid, and in the metabolism of certain amino acids—particularly histidine.

Both sheep and rats fail to metabolize histidine when rendered vitamin B_{12}-deficient, and this disorder is apparent by the excretion of considerable quantities of formiminoglutamic acid, an intermediary product of degration of histidine. The interplay is being studied of vitamin B_{12} and folic acid in this sequence of metabolic events.

The discovery that ruminant capacity to metabolize proprionic acid is seriously impaired when vitamin B_{12} status is reduced below a certain level by dietary deficiency of cobalt was mentioned in previous reports in which the tolerance tests with paired animals was described.

In vitro studies were undertaken of the relative rates of disappearance of propionate from homogenates of livers from carefully paired normal and vitamin B_{12}-deficient sheep. Capacity to convert propionyl coenzyme A to methyl-malonyl coenzyme A, an essential step in the intermediary metabolism of proprionate, failed progressively as the state of vitamin B_{12} deficiency worsened.

Later, demonstration that this isomeric change failed also in vitamin B_{12}-deficient rats suggested that this is a basic metabolic lesion common to all animals suffering a shortage of vitamin B_{12}.

Applications of these observations to problems of cobalt deficiency in grazing ruminants are referred to in Chapter VII.

10. PLANT NUTRITION.

(Division of Biochemistry and General Nutrition.)

Physiological study continued of the function of zinc in plants and of the anatomical lesions that supervene when pasture species become zinc deficient. A brief précis of the findings is reported in Chapter III., Section 8.

11. PROVISION OF COBALT TO RUMINANTS BY HEAVY PELLETS.

(Division of Biochemistry and General Nutrition.)

This work is described in Chapter VII., Section 7.

VII. SHEEP.

1. GENERAL.

With the remarkable post-war growth in Australia's secondary industries, agricultural and pastoral products have ceased to monopolize the industrial scene.

However, wool is still Australia's major export, and products such as wool, lamb, mutton, and hides comprise up to 45 per cent. of rural production.

This continent furthermore has abundance of good pasture ideal for sheep raising, together with vast areas of marginal land, which so far has proved unsuitable for other than pastoral purposes.

Current success of the synthetic fibre industry has given Australia an urgent interest in ensuring that wool can withstand competition from these fibres.

In an integrated research programme on problems of the wool industry, the Organization investigates every phase of sheep and wool production; soil, pastures, nutrition, genetics, animal husbandry, wool processing, textile manufacture, and the exploitation of by-products. The Organization has been given responsibility by the Commonwealth Government for carrying out this extensive programme, and special funds have been set aside for this purpose.

Soil fertility is obviously of prime importance, and outstanding results have been achieved in remedying soil infertility arising from minor element deficiencies. On the plant side, emphasis has been placed on pasture improvement and weed control. Work of the Organization on soils, pastures, and related matters affecting the pastoral industry is carried out by the Division of Soils, the Division of Plant Industry, and the Division of Entomology (see Chapters II., III., and IX.).

Work on the sheep itself has been undertaken within the Division of Animal Health and Production (see Sections 10-19 and 21-22 of this Chapter) and the Division of Biochemistry and General Nutrition (see Sections 2-9 of this Chapter). The Division of Mathematical Statistics is closely associated with the breeding investigations. The Animal Genetics Section's work on sheep breeding is described in Section 15 of this Chapter, and that of the Division of Entomology on the sheep blowfly in Section 20 of this Chapter.

The Organization's investigation of wool processing and wool textile problems is undertaken at the Wool Research Laboratories and the Chemical Research Laboratories (see Chapter XVI.).

2. NUTRITION AND WOOL PRODUCTION.

(Division of Biochemistry and General Nutrition.)

Studies continue of biochemical transformations involved in wool growth. Conversion of fodder proteins to wool protein entails intermediary processes of low efficiency when contrasted with those involved in conversion of fodder proteins to meat protein. Knowledge of factors determining rates of proliferation and keratinization of the follicular cells comprising wool fibres is essential in assessing effects of nutrition on wool production. The aim of these investigations is to increase the efficiency of pasture utilization for wool production. These studies have been closely associated with research of energy metabolism (see Section 4 of this Chapter).

3. MICROBIOLOGY OF RUMINATION AND FUNCTIONS OF FORESTOMACHS.

(Division of Biochemistry and General Nutrition.)

(*a*) *Passage of Digesta through Sheep Forestomachs.*—New markers have been developed to study the passage of fluid from rumen to omasum. The passage of soluble but indiffusible substances is being compared with the passage of lignin from the rumen under different conditions to study symbiotic microorganisms functioning in the rumen.

(*b*) *Distribution of Rumen Nitrogen and Conversion of Plant to Microbial Nitrogen.*—Study continues of the distribution of nitrogen in omasal contents and in the contents of the rumen.

(*c*) *Absorption and Interconversion of Ruminal Volatile Fatty Acids.*—Introduction into the rumen of experimental sheep of fatty acids labelled with ^{14}C in carboxyl carbon together with the marker, polyethylene glycol, via the fistula, allowed assessment of relative rates of absorption. Interconversion between ruminal fatty acids was assessed similarly by studies *in vitro*. The findings have been published in a series of papers.

4. ENERGY METABOLISM OF SHEEP.

(Division of Biochemistry and General Nutrition.)

Experiments are in progress to determine physiological mechanisms underlying the specific dynamic effect of protein, which is one of the outstanding phenomena associated with the thermodynamics of food utilization by higher animals. Nitrogen turnover estimates by $^{14}N/^{15}N$ ratios, after administering ^{15}N-enriched glycine, is being studied at different levels of protein intake in relation to the rate of energy dissipation determined by indirect calorimetry. These experiments have been planned to provide basic information in the poorly understood subject of energy metabolism.

5. CARBOHYDRATE METABOLISM OF SHEEP.

(Division of Biochemistry and General Nutrition.)

Studies of utilization of carbohydrates by adult sheep and young lambs continued. The ability of ruminants to mobilize glucose from reserve stores and the role of insulin in the intermediary metabolism of adult sheep and lambs are being studied with techniques employing ^{14}C-labelled glucose.

6. MINOR ELEMENTS IN SHEEP NUTRITION.

(Division of Biochemistry and General Nutrition.)

Disabilities imposed on grazing animals by shortages of minor elements in pastures are now known to be more widespread in Australia than originally suspected.

Studies of the maladies of sheep confined to regions where deficiencies prevail, indicate that extensive areas of grasslands are sufficiently short of cobalt, for instance, to seriously impair production and to cause, seasonally, ill health in flocks grazed there.

Now that simple means have been evolved to deal with cobalt deficiency, attention is being directed to ways of delineating regions limited by this deficiency. Procedures for overcoming the disabilities may then be applied.

The cobalt (i.e. vitamin B_{12}) status of an animal may be assessed by microbiological estimation of vitamin B_{12} concentration in the liver. Collection of liver samples by biopsy from animals in the field is, however, a skilled procedure involving risk to the animal.

The relationship is being studied between concentrations of vitamin B_{12} circulating in sheep's blood and the concentration of vitamin B_{12} in the liver to determine whether the sheep's vitamin B_{12} status may be assessed, with sufficient accuracy for diagnostic purposes, from concentration of this vitamin in the blood.

The concentration of vitamin B_{12} in blood is much less than in liver, and sensitive assays are required for its estimation. Methods employing strains of a unicellular flagellate, *Euglena gracilis*, are being examined. These may be developed into a very sensitive means of estimating vitamin B_{12} in animal tissues—one part of the vitamin added to a million million parts of solution will give a measurable response in the proliferation rate of the organism. Results of these investigations suggest that means of assessment of vitamin B_{12} status will be evolved that are suitable for survey purposes.

Though responses to treatment in areas of incipient cobalt deficiency are expected to be more subtle than those in clearly deficient areas, overall economic returns from treatment could exceed considerably the excellent returns observed in areas already known to be deficient. It is suspected that incipiently deficient terrain is much more extensive than these latter areas.

(*a*) *Cobalt Deficiency in Ruminants.*—Investigations of metabolic disturbances occurring when ruminants suffer shortage of cobalt have been extended, and greater understanding has been gained of the nature of the malady. Previous research revealed inability in vitamin B_{12}-deficient sheep to metabolize propionic acid normally. Biochemical search for the metabolic lesion has revealed a breakdown of the enzyme system which, in normal metabolism, converts propionyl coenzyme A to methyl malonyl coenzyme A, an isomeric transformation in which a complex of vitamin B_{12} probably plays an essential role. Any restriction of the metabolic channel dealing with propionic acid is particularly serious for ruminants because this acid comprises a large proportion of the fodder fermentation products within the rumen.

Sheep supported on cobalt deficient rations for a considerable period develop other metabolic defects, among which are partial failure of processes dealing normally with certain amino acids (histidine, tryptophane, and glutamic acid, for instance), and failure of processes necessary for maturation of red blood cells. These are under investigation. In these processes, involving production and transfer of fragments containing single carbon atoms, complexes containing vitamin B_{12} and complexes containing folic acid both play essential roles.

The response of some of these metabolic defects to treatment with one or other of these vitamins is that which might be expected from mass reaction effects upon chains of chemical events involving both vitamins.

(*b*) *Copper Deficiency in Ruminants.*—Experiments on the absorption and utilization of copper by ruminants have been completed and the results are being prepared for publication. Meanwhile all available pen space is being employed for work on cobalt deficiency.

Current work on copper deficiency at the Robe Field Station has mainly been concerned with testing heavy, copper-containing pellets claimed by others to provide effective amounts of copper to grazing sheep. The tests at Robe refuted these claims, which were contrary to the Division's experience gained from twenty years' studies of copper deficiency.

The suggestion that these heavy pellets comprised essentially of copper oxide were an effective source of copper for sheep was questioned in the previous Report. It was thought probable that free hydrogen sulphide present in rumen contents would ensure that both the surface of such a pellet, and particles freed from it, would become coated with copper sulphide and so rendered insoluble in intestinal secretions.

Pellets on which these claims of success had been based were obtained and subjected to tests. After a year of observations it is now possible to report unequivocally that these pellets failed to maintain a normal copper status in sheep confined to copper deficient terrain and failed to provide enough copper to effect any improvement in sheep that had been rendered copper deficient. It is most improbable that pellets of this nature will find successful application for the provision of copper to ruminants.

7. PROVISION OF COBALT TO RUMINANTS BY HEAVY PELLETS.

(Division of Biochemistry and General Nutrition.)

Experiments on retention of heavy objects in ruminant forestomachs now clearly indicate that pellets comprised of steel (sp. gr. 7.7) are unlikely to be lost under usual grazing conditions. All pellets have been retained for two years by test animals subjected to a variety of grazing conditions. In these tests, X-ray observations revealed that over a period of two years a proportion of the pellets comprised of cobalt oxide and clay (sp. gr. 4.0) were lost, and that pellets comprised of 10 g. of a mixture of cobalt oxide and finely divided iron (sp. gr. 5.0) were, like the denser pellets, all retained. Thus the modified and more efficient pellet promised when Formula A was released is likely to be announced soon.

With this in view a number of different types of pellets of cobalt oxide and iron powder in various proportions have been prepared and are being tested.

Formula A pellets were introduced as a tentative measure for combating cobalt deficiency, and for prevention of phalaris staggers until more perfect pellets were developed. They have been successful, but are by no means the ideal device for securing the requirement of cobalt throughout the natural life of a ruminant.

It is evident that pellets of higher density will ensure retention of a cobalt source in forestomachs, and introduction of other devices into the rumen along with the pellet will ensure extension of its efficacy for a longer period. Some of these devices are referred to in Section 8 of this Chapter—phalaris staggers.

8. PHALARIS STAGGERS.

(Division of Biochemistry and General Nutrition.)

Previous reports have referred to the fatal malady phalaris staggers suffered by sheep and cattle confined to *Phalaris tuberosa* dominant pastures, and to the discovery that this malady may be prevented if cobalt is administered *per os* frequently enough to keep the cobalt concentration of the rumen contents above a level that provides for all requirements of the rumen flora.

Heavy cobalt pellets were developed to ensure that these conditions would prevail constantly within the rumen contents.

In the first series of studies, made 8-12 weeks subsequent to the administration of the pellets, protection was complete under conditions that led to losses of up to 60 per cent. of the untreated controls. Later studies continued over a much longer period revealed the hazards of loss of some pellets by regurgitation, and under certain conditions loss of effectiveness of others through deposition of calcium phosphate as a concretionary layer upon them. Experiments (see Section 7 of this Chapter) showed conclusively that the former hazard may be dispelled by increasing the density of the pellets. The latter hazard may be mitigated if not dispelled completely by employing more friable pellets, and by providing means within the rumen which will keep their surfaces clean by abrasion. This may be effected either by introducing two pellets instead of one, or by introducing another heavy object—a ⅜ by ½ in. grub-screw, for instance—along with the pellet.

Conditions particularly favourable for development of phalaris staggers were initiated this year in the south-east of South Australia by early heavy rains. The phalaris pasture responded vigorously, and subsequent unprecedented dry weather discouraged development of annual species. In these circumstances the greater proportion of the untreated control sheep developed staggers—at one observation site sixteen out of eighteen became affected within a few weeks, whereas all treated animals were protected.

In June the toxicity was such that untreated healthy sheep developed the malady within six days of being transferred to the practically pure stand of phalaris which then prevailed. Under these extreme conditions a proportion of the sheep treated with single pellets three months previously became affected. Those treated with two pellets, however, were all protected. The fact that normal concentrations of vitamin B_{12} were observed in rumen contents taken from animals which had been treated with a single pellet and had subesquently developed the staggering syndrome, provided direct evidence that a greater concentration of cobalt may be necessary to protect the grazing ruminant when the toxic potential of phalaris pastures is particularly high.

The extremely high toxic potential of phalaris pastures that prevailed at observation sites this year rendered possible a survey of acetyl cholinesterase activity in the blood of sheep at various stages of the syndrome. The observation that blood acetyl cholinesterase was not significantly less active in sheep at any stage of the malady than in normal (cobalt-treated) sheep suggests that the neurotoxic principle arising from *Phalaris tuberosa* does not function as an anticholine esterase. Biochemical studies were made on the brain tissue of seriously affected animals in an attempt to locate the metabolic lesion.

9. SALT TOLERANCE AND POTABILITY OF STOCK WATERS.

(Division of Biochemistry and General Nutrition.)

The third of the series of experiments to determine the limit of the sheep's capacity to tolerate various salts which occur naturally in bore-waters was completed. These observations proved that sheep suffer no untoward effects when confined to water containing up to 0.9 per cent. of sodium chloride, and that at the level of salt intake they tolerated additions up to 0.5 per cent. of sodium sulphate. In the fourth experiment of this series the effects of various concentrations of magnesium salts will be investigated.

These experiments afforded an opportunity to study the mechanisms by which some animals become adapted to saline waters of relatively high concentrations. Changes in electrolyte concentrations within the blood of the experimental animals are being studied at intervals throughout the periods of observation.

Experiments to ascertain the nature of changes occurring in the kidneys of sheep confined to waters of high saline content are now in progress. The results should clarify the adaptive adjustment exhibited by sheep subjected to these stresses.

10. METABOLISM AND NUTRITION OF SHEEP.

(Division of Animal Health and Production.)

(*a*) *Pregnancy Toxaemia Investigations* (Sheep Biology Laboratory, Prospect).—The aetiology of pregnancy toxaemia may be summarized as follows:—The pregnant ewe, especially when carrying well-grown twin foetuses, is highly prone to undernourishment with development of hypoglycaemia. This, together with concurrent stresses of environmental or psychological origin, leads to excessive secretion of cortisol by the adrenal glands. The combined effects of hypoglycaemia and elevated plasma cortisol concentration lead to impairment of liver function and metabolism of peripheral tissues, which in turn are expressed in hyperketonaemia and depression of the central nervous system with attendant symptoms recognized as "pregnancy toxaemia". Numerous observations in the field and laboratory have established that pregnancy toxaemia is merely the terminal phase of stress reactions, and that all grades of response to stress occur. Hence, the occurrence of a few cases of pregnancy toxaemia will usually indicate that many other ewes in the flock are undernourished. These findings offer clear indications for practical prevention of the disease.

Ewes have been exposed to controlled environmental stress (cold, wet, and wind) for short periods in the climate rooms at Prospect. This work indicated the importance of duration of stress and of the size of foetal lambs as contributing factors to precipitation of pregnancy toxaemia. The effects of psychological stress are currently being examined.

Detailed observations were made on field cases of the disease in Tasmania. The adrenal glands were enlarged, plasma cortisol levels were higher than normal, and these two deviations were correlated.

(*b*) *Feed Requirements of Ewes in Late Pregnancy and Lactation.*—Concentration of blood glucose proved an extremely sensitive criterion of undernutrition of pregnant ewes, provided tests were made under rigidly controlled conditions. When feed intake of ewes was reduced four weeks before lambing, ewes with single lambs were able to compensate quickly while those with twins failed to compensate and became hypoglycaemic and hyperketonaemic. Data on birth weights of the lambs suggests that these observations explain the results of field experiments in which birth weights of single, but not twin, lambs may be unaffected by undernourishment. This experiment also indicated that ewes with well-grown twin foetuses may be unable to consume sufficient of a roughage diet to maintain maternal body weight; this could be due to lack of space in the abdominal cavity, since *ad lib.* food intake increased markedly on the day of lambing.

Failure to increase the amount of food offered after lambing caused marked loss of body weight during early lactation. Milk production was maintained at high levels at the expense of maternal body tissue. Yet the hypoglycaemia and hyperketonaemia which characterize such a degree of undernutrition in the ewe in late pregnancy were almost absent; it is likely that the ketosis so commonly occurring in cows under such conditions may not be readily induced in ewes.

(*c*) *Digestion in the Rumen.*—Radioactive chromium as the complex with ethylenediaminetetraacetic acid (^{51}Cr-EDTA) has been examined as a possible soluble marker for use for use in studies on ruminant digestion in comparison with polyethylene glycol. The two markers seem to behave identically in the rumen, and can be used for estimating rumen volume and rate of passage of solutes, and indirectly for measurements of absorption. Marked changes occur in the rate of flow through the rumen. From available data, no definite pattern is discernible and no apparent relation to feed consumption, time after feeding, or time of day. Absorption of ammonia, the principal nitrogenous metabolite in the rumen, increases with increased concentration of ammonia or volatile fatty acid. The rate was not influenced by concentration of lactate, sodium, potassium, chloride, or carbon dioxide, nor by variations in net movement of water into or out of the rumen.

(*d*) *Nitrogen Metabolism in the Sheep's Rumen.*—Except at high intakes of non-protein nitrogen the concentration of rumen ammonia falls to extremely low levels, suggesting that bacterial uptake of ammonia exceeds the rate of nitrogen addition to the rumen by salivary secretion and diffusion through the rumen wall. Concurrent with the low rumen ammonia, there is a marked fall in blood urea concentration, indicating a highly efficient utilization of nitrogen. The nitrogen metabolism of rumen bacteria is being studied under *in vitro* conditions. Techniques are being developed to measure microbial synthesis in the rumen by following the incorporation of radioactive sulphur into microbial proteins after inorganic sulphate has been fed.

(*e*) *Protein Metabolism of Sheep.*—The capacity of the sheep to synthesize amino acids has been studied by intravenous injection of ^{14}C-labelled acetate into a lactating ewe. Individual amino acids, except tryptophane, were isolated from milk casein and the specific activities determined. As in the cow, negligible activity was found in tyrosine, phenylalanine, isoleucine, leucine, valine, methionine, cystine, threonine, lysine, and histidine. The sheep's requirement of essential amino acids resembles closely that of man, rat, and bovines.

Radioactive sulphur was used to determine the immediate precursors for wool synthesis. (^{35}S) DL-cystine was injected intravenously and samples of wool and plasma proteins were subsequently analysed. Plasma amino acids, and not plasma proteins, are apparently the precursors of wool. Since cystine may have a special function in wool synthesis, similar experiments are being undertaken with other labelled amino acids.

(*f*) *Energy Metabolism of Sheep.*—In wool growth experiments it was found that the maintenance energy requirement of sheep is strongly dependent on the degree of body condition maintained. This relation will be further examined.

11. DROUGHT FEEDING.

(Division of Animal Health and Production.)

Drought feeding experiments with sheep continued in the McMaster Laboratory in collaboration with the New South Wales Department of Agriculture at the Veterinary Research Station, Glenfield. Financial support was again provided by the New South Wales Graziers' Association from the Burdekin Bequest Fund.

(*a*) *Utilization of Low-quality Roughage.*—In the sixth experiment in this series, data were collected on the performance of groups of two-tooth Merino wethers in yards when fed on three different types of roughage. These contained 2.6, 4.2, and 5.8 per cent. crude protein respectively. In addition, 4.5 oz. wheat grain per head per day, alone or with three different levels of a urea-sodium sulphate mixture, were fed at twice-weekly intervals. The optimum level of urea under these conditions was 6 g. per day and there was only slight response to urea in the high-quality roughage groups.

(*b*) *Influence of Nutrition on Breeding Performance of Merino Ewes.*—Studies were made on the effect of two energy levels, each at two different levels of nitrogen, on breeding performance and wool growth. There were no significant differences in lambing performance between the four treatments. There was no response in wool production to urea at either energy level. No cases of urea poisoning occurred although mean daily urea intakes of up to 15 g. were recorded. At the end of the experiment treatments were reversed overnight without apparent harmful effects from urea. All-grain goups were changed overnight to wheaten chaff and lucerne chaff only, without the occurrence of digestive upsets.

(*c*) *Vitamin A Studies with Merino Lambs.*—Lambs were weaned into two groups at age 8-9 weeks and were fed a ration of low-quality roughage (2.6 per cent. crude protein) 40, oats 28.5, linseed meal 30, and limestone 1.5 parts by weight. Plasma vitamin A levels for both groups averaged 19.9 per 100 ml. One half of the lambs were treated orally with 20,000 I.U. of vitamin A per lb. bodyweight. Plasma vitamin A levels of the treated lambs were 25, 36, 27, and 29 μg. per 100 ml., 2, 4, 6, and 8 weeks respectively after treatment. Corresponding data for the untreated lambs were 13, 8, 2, and 3 μg. per 100 ml. Under the conditions of this experiment dosing with vitamin A improved survival rate, growth rate, and appetite.

12. TOXICITY OF LARGE RATIONS OF WHEAT.

(Division of Animal Health and Production.)

Investigations terminated on this problem at the Animal Health Laboratory, Melbourne, with the completion of the studies on haemodynamics and red cell storage in sheep. These were undertaken to explain phenomena observed during the major investigation. Simultaneous estimations of red cell volume, by using ^{51}Cr-labelled red cells, and of plasma volume by means of T.1824, demonstrated that the ratio of body haematocrit to jugular haematocrit, used in calculating blood volume from plasma volume and jugular haematocrit, was related to the state of contraction or dilatation of the spleen, and that it might range from 0.80 to 0.86 in splenectomized sheep to 1.32 in very placid sheep. Rise in jugular haematocrit after intravenous adrenalin is due mainly to redistribution of cell-rich splenic blood in the extrasplenic circulation, and rheological effects due to vasomotor actions of adrenalin are unimportant. Splenic blood may contain 70-90 per cent. of cells and the spleen retain in dynamic equilibrium 30-40 per cent. of the total red cells of the body.

13. INFERTILITY AND PHYSIOLOGY OF REPRODUCTION.

(Division of Animal Health and Production.)

(*a*) *Seasonal Variation in Sexual Activity of Merino Sheep* (Sheep Biology Laboratory, Prospect).—Further observations were made on the complex factors involved in seasonal effects on reproduction. Contrary to earlier findings, shearing had no influence on the incidence of oestrus in November, 1958. Other observations at Tooradin showed clearly that ewes in close association with rams for two weeks at the end of November and early December were stimulated to sexual activity. Control ewes separated by ¼ mile from rams showed only slight activity in December.

Experiments on ewes both at Parkville and Tooradin have shown clearly that some factors other than length of light period (daylight or artificial light) determine establishment and maintenance of seasonal variation in sexual activity in Merino ewes. Seasonal variation, with anoestrus in the spring, was observed in ewes exposed to continuous light (daylight plus artificial light at night), but not protected from other environmental changes. No appreciable differences were detected in the gonadotrophin content of the pituitaries of Merino ewes killed at different times of the year.

(*b*) *Precise Control of Ovulation Time in Ewes.*—Experiments with 100 Merino ewes have shown that time of ovulation can be controlled within about ± 4 hr. by a technique involving injection of progesterone for 12-16 days followed by injection of pregnant mare serum gonadotrophin and, 1-2 days later, an injection of human chorionic gonadotrophin. The technique will be valuable in studies on phenomena associated with sperm transport and fertilization in ewes, and may have application in large-scale artificial insemination of sheep.

(*c*) *Infertility on Red Clover Pastures* (Regional Pastoral Laboratory, Armidale).—Nineteen per cent. of fine-wool Merino ewes grazed on red clover dominant pastures during eight of the eleven months prior to mating subsequently failed to lamb compared with 12 per cent. in a control group.

(*d*) *Fertility of Rams* (Sheep Biology Laboratory, Prospect).—Research on fertility of rams has been initiated as a major project. Preliminary observations on seasonal variation in semen quality are being made on Merino rams grazing improved pasture. Changes in volume of ejaculate, sperm concentration, sperm motility, proportion of live sperm, and fructose concentration are being examined at monthly intervals.

In a temperate environment testes of the ram are at a temperature several degrees below that of the abdominal cavity. As has been shown for other mammals possessing scrotal testes, it is thought that this temperature gradient must be maintained for normal spermatogenesis to occur. It is proposed to study the mechanisms whereby this gradient is preserved and conditions under which it may be disrupted.

Features of testicular vasculature suggested to others the possibility of heat transference from the internal spermatic artery to the veins of the pampiniform plexus as a means of precooling arterial blood perfusing the testis. This is being examined by recording simultaneously blood temperature in different parts of the testis vascular system.

The internal spermatic artery in its course between the inguinal canal and the dorsal pole of the testis convolutes in many tight spirals before undulating over the surface of the testis. In an adult ram the length of artery involved in the convolutions is more than 2 metres. Many characteristics of this structure suggest that it has haemodynamic properties. It has been shown that mean blood pressure drops significantly along its length and that alterations in the pulsatile nature of the blood flow occur. The magnitude and possible implications to normal testicular function of the effects observed will be examined in future experiments.

The morphological characteristics of scrotal skin which may be concerned with temperature regulation are being examined as a preliminary to study of its possible role in maintenance of testicular temperature gradient.

(*e*) *Ewe-marking Crayon for Rams.*—In collaboration with the Division of Textile Industry, a successful crayon and harness has been devised for detection of mating. The crayon is held on the ram's brisket and, under field conditions, gave satisfactory marks for at least two weeks; the marks are distinguishable for at least four weeks and are readily scoured from the fleece. The device will facilitate experimental work on reproduction, but will also have application in stud work for identification of ewes mated or in oestrus, and in general sheep husbandry for more efficient control of both mating and lambing.

(*f*) *Effect of Nutrition During Growth on Productive Performance* (Regional Pastoral Laboratory, Armidale).—Groups of fine-wool Merino ewes were kept on a low level of nutrition over either the first or second six months of life and compared with ewes which received no check. At the first lambing 33 and 34 per cent. of ewes in the two checked groups did not lamb compared with 25 per cent. in the unchecked group. There was a negative relationship between the amount of face cover and lambing performance, but this was confounded with liveweight differences.

(*g*) *Effect of Nutrition During Pregnancy.*—Fine-wool Merino ewes after grazing on either medium or low planes of nutrition (constant weight and losing weight, respectively) were fed *ad lib.* in pens for either nil, three, or six weeks immediately prior to lambing, and their performance compared with that of ewes making substantial and sustained weight gains on continuous high-plane grazing. In birth weight, losses, lamb growth to weaning, and ewe wool weights, nutrition in late pregnancy under these circumstances had a smaller effect than that imposed earlier, except that losses of ewes and lambs were highest in the continuous low-plane group.

Under grazing conditions fine-wool Merino ewes lambed in fat to very fat condition (mean liveweight 119 lb.) had lambs of heavier birth weight than ewes in forward store to fat condition (mean liveweight 106 lb.).

(*h*) *Neonatal Lamb Physiology* (Sheep Biology Laboratory, Prospect).—Previous observations had shown that new-born lambs were liable to die on cooling rapidly after birth. Temperature regulating mechanisms have been studied using a calorimeter in which the lamb's heat production could be measured at low temperatures, with controlled wind velocities, and with the coat wet or dry. Under severe conditions, the maximum heat production of lambs was 14-24 cal./kg./hr., was independent of body weight over the range 2-5 kg., and was similar in singles, twins, and triplets and in both Merino and crossbred lambs. From these data the environmental conditions can be calculated under which new-born lambs can just maintain constant body temperature. Striking differences in resistance to exposure were found between lambs from well-fed ewes and grossly underfed ewes.

Fat has been shown to be the major source of energy for new-born lambs, but even when ewes are very well fed, the lamb's body contains only 3 per cent. fat. Thus, especially in severe weather, it is imperative for the lamb to obtain nutriment soon after birth. Great increase in heat production under cold stress is accompanied by substantial elevation of blood glucose. In the foetus, fructose is a major component of the blood sugar, but fructose is not readily utilized by the central nervous system of the lamb.

(*i*) *Neonatal Mortality in Lambs.*—Australian data indicate many causes of death in new-born lambs operating concurrently, even in the absence of infectious diseases. During 1958, observations were made in Victoria on a Corriedale flock in which heavy losses among lambs had occurred every year. Lambings were arranged for August and October; inclement weather accounted for half the deaths in August, but only a third of the losses in October. The results were complicated by marked differences in percentage of twins in the two groups, but a high death rate in the twins had the effect of giving similar lamb-marking percentages to the two groups. Other experiments have shown that when lambs were prevented from sucking for some hours after birth the drive to suck the teat declined but rapidly returned when the lamb was placed at the teat and allowed to suck. Work continued on the negative pressure required to cause emission of milk from the teat.

The role of maternal behaviour in lamb survival has been studied by detailed observations on maiden and mature ewes kept under identical conditions during pregnancy and lambing; over 20 per cent. of the maiden ewes abandoned their lambs at birth compared with only 1 per cent. of the mature ewes. The pain and shock associated with parturition, apparently more severe in maidens, may depress the maternal instincts in the inexperienced ewes.

(*j*) *Feed Intake of Suckling and Weaned Lambs on Summer Pasture.*—Consumption of milk by suckling lambs led them to consume less pasture than weaned lambs of the same age. This experiment was repeated under controlled conditions with lambs 3-3½ months old. Feed intake, as estimated from faecal output, was almost twice as much in weaned as in suckling lambs. This observation is important to the practice of early weaning of lambs.

14. BREEDING AND GENETICAL STUDIES.

(Division of Animal Health and Production.)

(*a*) *Inbred Flocks of Australian Merinos* (McMaster Field Station).—Inbred lambs injected with deep frozen pituitary extract gave a much less dramatic response in growth rate than that reported last year. After six weeks' use it was replaced with freshly prepared extract and the lambs then responded as they had done in the previous experiment. When tested by bioassay the growth hormone content of the deep-frozen extract was found to be normal. It is not known to what extent other hormones may have been affected. There is presumptive evidence, therefore, that growth hormone alone is not responsible for effects observed when inbred lambs are injected with freshly prepared pituitary extract. A breeding programme is now in progress to provide animals for experimental work with fractionated material.

(*b*) *Inheritance of Fleece Characters.*—The final lambing has taken place but collection of fleece data will require two more years. Preliminary examination of skin biopsy material from a sample of F_1 animals revealed a greater variance in primary to secondary ratios in the F_2 than in the F_1 generation.

(*c*) *Heredity × Environment Interactions* (McMaster Laboratory).—Analyses of results comparing five Merino strains in three environments are complete. Poor lambings in one year have necessitated another year's mating for adequate comparison of progeny from the same ram in different environments.

(*d*) *Selection of Individual Sheep—Experimental Results.* (i) *Results of Selection for Clean Wool Weight.*—Six years' selection for clean wool weight led to an increase of ¾ lb. clean wool per head for sixteen-month-old ewes. The increase arose from a greater mean number of fibres per unit skin area and a greater mean staple length; there was no change in body weight or in two characters on which a ceiling was placed (wrinkle score and fibre diameter). In spite of lack of change in fibre diameter, number of crimps per inch was two less in the selected group than in the control. Fleeces from both groups will be processed this year at the Division of Textile Industry to see whether the difference in crimp, with no change in diameter, has any detectable effect in manufacture. In addition, one group will in future be selected on clean wool weight with a limit on crimp instead of diameter.

There has so far been no consistent difference between selected and control groups in the number of lambs weaned per ewe mated, and death rates in ewes have been similar.

(ii) *Results of Selection for High Twinning Rate.*—In five subsequent lambings, base ewes selected for bearing twins in two years have dropped on the average 1.30 lambs per ewe mated, and the ewes selected for bearing singles, 0.97. Young ewes born in the first group have averaged 1.12 lambs dropped per ewe mated in their first three lambings, and those in the second group, 0.93.

(iii) *Selection for Mutton Characteristics in Merinos.*—Lines for good and poor mutton conformation were selected in three strains and mated in May 1958, selection being based mainly on visual appraisal of a photograph of each animal. Work on finding satisfactory objective criteria for selection is continuing.

(*e*) *Selection of Individual Sheep—Theoretical Studies.*—(i) *Selection for More than One Character.*—The classic work of Hazel and Lush in 1942 in comparing methods of selecting for more than one character was restricted to certain simple sets of conditions. This study has been extended to cover a wider range of cases, including correlated characters. In terms of genetic progress in economic return, a selection index combining characters into a single score is never less efficient than other methods, but is sometimes no more efficient than selecting for each character independently and may frequently be more costly and slower in application.

Another way of combining characters is in the form of a ratio, for example, production per pound of body weight. Formulae have been developed for expressing heritability of the ratio and its correlation with its components in terms of the parameters of the components. The genetic correlation of the ratio with its denominator is nearly always negative, so that selection for high values of the ratio will decrease the character appearing as the denominator. Selection on wool weight per pound of body weight in sheep, for example, will often lead to decreased body size.

(ii) *Standard Errors of Genetic Correlations.*—A method has been developed for estimating the errors of genetic correlation when calculated from analyses of variance and convariance.

(*f*) *Genetics of Fleece Structure.* (i) *Crimp-Diameter Studies.*—Selection is based on high and low values of an index combining crimp and diameter. The aim is to study the extent to which crimp-diameter relationship can be varied by selection. Further studies of the relationship are also being made in a fine-wool strain additional to the one previously studied.

(ii) *Crimp-Length Studies.*—Rams from a strain characterized by high crimp number and long staple have been mated to medium Peppin ewes and selection for long staple plus high crimp will be made among the offspring.

(*g*) *Permanent Effects of Environment.*—Wethers of five strains born in 1950, some at "Gilruth Plains" and some at Armidale, have been run together at "Gilruth Plains" since 1952. Those dropped at Armidale suffered an early check still discernible in 1958. The wethers were slaughtered at Armidale in 1958, and, in collaboration with Professor N. T. M. Yeates of the University of New England, certain bones and muscles were dissected out for detailed measurement.

(*h*) *Hornedness in Sheep* ("Gilruth Plains", Cunnamulla).—(i) *Inheritance of Hornedness.*—The current hypothesis on inheritance of long scurs and aberrant horns *Pp* rams is that two pairs of alleles are concerned and that these horn types result when at least one dominant gene from each pair of alleles is present. A limited number of matings has suggested that the horns in Dorset Horn ewes and in Merino ewes result from the action of the same dominant gene, *P*′. Matings have been made to test this further. If it is confirmed, the major difference between Dorset Horns and Merinos (other than Poll Merinos) so far as hornedness is concerned, would be that the Dorset Horn is homozygous for *P*′, whereas in the Merino *P*′ and *p* are segregating with *P*′ generally at a low frequency.

(ii) *Hornedness and Production.*—Introduction of the gene *P* to "Gilruth Plains" flocks has not been associated with a change in wool production per head or in body weight when *Pp* and *pp* animals are compared; no difference in wool production or body weight has been demonstrated between ewes with and without horns.

15. GENETICS OF SHEEP.

(Animal Genetics Section.)

A review of the present status of research into the determination of fleece structure has been compiled.

Current projects have, naturally, been reappraised in the light of conclusions reached. The relative importance of variation of size and number of follicle groups in determining fleece structure are being estimated from two selection experiments: one at Armidale, the other at Canberra. Size of follicle groups has little, if any, effect on wool production. A Fulbright student, R. Klay, has extended research on sheep mosaic for fleece type, making comparisons between different levels of feeding. As a consequence of the increased demands for histological data, a very fast method was devised of obtaining histological sections of skin which has allowed a considerable expansion of the number of sheep examined in this way.

16. BIOLOGICAL STUDIES ON SKIN AND WOOL GROWTH.

(Division of Animal Health and Production.)

(*a*) *Endocrinology of Wool Growth* (Sheep Biology Laboratory, Prospect). (i) *Wool Growth and Anterior Pituitary Gland.*—Suppression of wool growth following hypophysectomy is not due to deficiency of a single hormone. Thyroid and adrenal cortical atrophy must be repaired with thyrotrophic and adrenocorticotrophic hormones respectively, or thyroxine and cortisol supplied before normal wool growth responses to other pituitary hormones can be obtained. In excess of their permissive levels, thyroxine and cortisol respectively stimulate and suppress wool growth so that dosages must be carefully adjusted before the response to other pituitary hormones can be studied. The normal levels of thyroxine and cortisol secretions are being determined in separate experiments with thyroidectomized or adrenalectomized sheep, prior to further examination of the wool growth response of hypophysectomized sheep to other pituitary hormones.

Starch gel has proved superior to filter paper and cellulose acetate membranes as media for zone electrophoresis of sheep pituitary proteins. A classification is being attempted of pituitary proteins according to their mobility on starch gel and other properties.

(ii) *Wool Growth and Thyroid Gland.*—Work at Prospect on this problem is integrated with work on the pituitary gland since the thyroid is under pituitary control. Negligible thyroid activity can be detected in hypophysectomized sheep using ^{131}I. The extent to which wool growth response to increasing feed intake is accompanied by and is dependent on an increase in thyroid activity is being investigated by measuring thyroid activity in normal sheep at different levels of feed intake, and measuring wool growth response to increased feed intake in thyroidectomized sheep.

At the Regional Pastoral Laboratory, Armidale, increases of up to 15 per cent. in greasy wool weights of fine wool wethers were obtained after treatment with thyroxine at various dose rates given once only or repeated at three-month intervals. Yield was depressed slightly and increase occurred in fibre length and diameter on good pastures. Repeated treatments of 90 mg. caused deaths of 50 per cent. of the wethers but repeated treatments with 30 or 60 mg. resulted only in temporary loss of weight. As estimated by the chromic oxide marker method the feed intake of sheep given repeated 60 mg. implants was increased by 20-40 per cent. consistent with the marked rise noted in pulse and respiration rates. Sheep recovered completely in 3-6 months and their wool growth, live weight, and feed intake returned to normal levels.

(iii) *Wool Growth and Adrenal Cortex.*—It has previously been reported that the adrenocortical steroids tend to inhibit wool growth. Measurement of thyroid secretion in adrenalectomized sheep maintained on different dose levels of cortisone acetate show that depression of thyroid secretion does not contribute to the depressant action of the adrenal cortex on wool growth.

(iv) *Zone Electrophoresis on Blood Proteins.*—This technique is being used to study concentrations of thyroxine-binding and cortisol-binding protein in sheep plasma. In the course of this work three new beta-globulin types and a new haemoglobin type have been discovered.

(*b*) *Efficiency of Conversion of Feed into Wool* (Sheep Biology Laboratory, Prospect).—In last year's report, efficiency of wool growth was defined as the proportion of crude protein intake converted into wool. Subsequent analysis of experiments relating wool growth to different energy and protein intakes has shown that wool growth response to increasing feed intake is due to increase in energy intake rather than to increase in crude protein intake for rations containing more than 8 per cent. of crude protein in the dry matter. The value of pastures and fodders for wool growth must therefore be judged on their net energy content rather than protein content when this is more than 8 per cent. on a dry matter basis. The relation of the energetic efficiency of wool growth to energy intake is being examined. Present results indicate that the exponential diminishing returns relationship proposed earlier only applies before equilibrium has been established at different levels of feeding. After equilibrium has been established wool growth appears more nearly proportional to energy intake. An equation has been developed relating the energetic efficiency of wool growth to the rate of body weight change which measures the degree of equilibrium attained at a particular level of feeding. The physiological nature of differences in efficiency of wool growth between individuals is being examined.

Observations are continuing on sheep with high and low levels of wool production to determine where major differences occur in conversion of feed to wool. A considerable proportion (possibly of the order of 30-50 per cent.) of the differences between animals in clean wool production under field conditions appears referable to differences in feed intake. Substantial differences in metabolic efficiency also exist, but differences between sheep in efficiency of digestion are not of much quantitative significance in productive capacity.

A large-scale breeding experiment has been commenced to study the heritability of efficiency of conversion and effect of selection for high and low efficiencies.

(*c*) *Skin and Fleece Development.* (i) *Effects of Lamb Nutrition.*—This experiment established that severe nutritional restriction during pregnancy, or between birth and four months of age, will restrict mature body weights and wool producing capacity. Differences between treatment groups in follicle population density were small and non-significant, although there was a large difference between groups in total number of follicles on the animals as a consequence of differences in skin area.

(ii) *Mitotic Rates in Wool Follicle Bulb.*—Within a given animal, there is a high correlation between fibre diameter and number of mitoses occurring in the follicle bulb during a given period of time. Investigations are being undertaken of fibre cortical cell number and size on the same experimental material. Attempts to maintain normal mitotic activity in follicle bulbs *in vitro* over short priods of time have not yet been successful.

(iii) *Post-natal Development of Wool Follicles.*—Post-natal development is being studied in both Merino and crossbred sheep; skin samples have been taken from experimental sheep between birth and two years of age.

(iv) *Follicle Branching.*—Observations commenced on the quantitative significance of follicle branching in relation to follicle group size in the major fleece types. Further observations have also been made on the prediction of mature follicle ratios from skin sections at birth. Owing to the fact that follicle branching occurs at variable levels, a section at any given level will almost invariably give an underestimate of the ratios. No evidence was found to suggest that any follicles are initiated after birth; this is in agreement with the earlier observations, but has been questioned by overseas workers.

(v) *Skin Histology of Some Indian Breeds of Sheep.*—During the tenure of a Colombo Plan Fellowship by Mr. M. V. Krishna Rao of South India, the opportunity was taken to study the follicle density and follicle group structure of six Indian breeds of sheep from the States of Andhra and Madras. This survey indicated the relatively primitive nature of some of the breeds, as judged from the extremely low follicle population densities, low secondary to primary follicle ratios, and very high primary to secondary fibre diameter ratios.

(*d*) *Fleece Structure and Wool Production.* (i) *Fleece Mosaics.*—Studies of skin from fleece mosaics are continuing to establish the source of the changed rate of wool growth on the abnormal regions of skin.

(ii) *Fleece-type Mutants.*—The felting lustre (Merino) mutant has been found to be controlled by a single dominant factor. These sheep are proving valuable in studies on the mechanism of crimping and the interrelations of various fleece characters. Substantial quantities of this lustrous, felting, Merino wool have now been supplied to the Division of Protein Chemistry and the Division of Textile Industry for both experimental and pilot commercial trials of its unusual textile properties.

In the "gog" (Merino) mutant, the major feature, lack of sweat glands, has been exploited in studies on sweating in sheep. "Carpet" mutants have been found in Merino, Corriedale, and Southdown breeds. Evidence points to a single recessive factor in each case. Skin and fleece data from several crossbred and Corriedale examples demonstrated that the major effect of the "gene" is on size of primary follicles and fibres (as it is in New Zealand *N*-type Romneys). There is no discernible effect on secondary to primary fibre ratio, primary fibre density, secondary fibre density, or wool production per unit area of skin.

(iii) *Skin Grafting.*—This technique was tested as a possible means of determining the physiological mechanisms which control growth of wool by the follicles. Grafts of maternal skin to the foetus have shown that the transition from immunological inertia to competence probably occurs at the very early age of about 70-80 days of foetal life. Lambs could not be made tolerant to homografts from their dams by injection of maternal spleen cells into the foetus or by replacing the new-born lamb's blood with maternal blood.

(iv) *Effect of Variation in Plane of Nutrition on Metric Fleece Characters*.—This experiment aims to establish the responses of wool follicles to major dietary change. The experimental animals have now passed through two cycles of restricted and *ad lib.* feeding. The experiment will be continued with the sheep maintained over a long period on a constant low-feed level. Variations in physical properties of fibres brought about by these cycles of restricted and unrestricted feeding are being examined in collaboration with the Division of Textile Physics.

(v) *Suint in Fleece*.—Measurements of suint content were made in wool samples from ten sheep with normal skin; the mean content was 14 per cent. of dry clean wool. This was compared with wool samples from four Merino sheep without sweat glands (the so-called " gog " mutants); three gave values about 8 per cent. and a fourth 17.5 per cent. Clearly sweat glands are not the only source of suint. There is in fact no evidence that they are a source of suint at all.

(*e*) *" Doggy " Wool*.—The fault known in the wool trade as " doggy " causes serious depreciation in sale value, but nothing is known of the biological mechanisms leading to this defect.

No definite abnormality in the wool other than crimping has been detected. Objective definition of dogginess therefor cannot be given. It is also not known whether a single fault is involved. Histological examination of skin from " doggy " sheep of both Merino and Polwarth flocks revealed definite abnormalities. There is enlargement of the outer root sheaths of follicles and, in some cases, cyst-like appendages to sheaths. Keratinization, similar to that of the stratum corneum, appears to have occurred in the capsules of the cysts. The zone of keratinization was also about half as long in " doggy " as in normal sheep. Cystine contents of " doggy " and normal wools were not significantly different. Influence of plane of nutrition on dogginess is being studied under controlled conditions in the animal house.

(*f*) *Autoradiography of Wool Fibres*.—After injecting sheep with (^{35}S) DL-cystine, autoradiographs have been prepared from skin sections and wool fibres. This technique provides information on the position of entry of cystine into the wool follicle, accurately identifies the time of formation of a part of the fibre, and also provides a means of accurately measuring the length of wool fibres grown over a short period of time.

17. SHEEP DISEASES.

(Division of Animal Health and Production.)

(*a*) *Jaundice in Sheep*. (i) *Chronic Copper Poisoning* (Animal Health Laboratory, Melbourne).—Interference by manganese in control of copper storage by molybdenum and inorganic sulphate has been further studied. Manganese has this effect only when the diet is low in protein and when the sulphate diet content is low enough to allow copper to accumulate. It is now clear that manganese interference can be overcome by increasing the animal's intake of either molybdenum or sulphate. It has also been demonstrated that administration of thyroxine significantly reduces rate of build-up of copper in the liver.

Studies on the form of copper in blood of normal sheep indicated that the distribution between red cells and plasma is determined by the concentration of loosely bound copper in the plasma rather than by the total plasma-copper concentration. Similar observations are being made on sheep during a haemolytic crisis.

(ii) *Action of Hepatoxic Alkaloids* (McMaster Laboratory).—The pyrrolizidine alkaloids of *Heliotropium europaeum*, but not their *N*-oxides, inhibit enzymes requiring pyridine nucleotide by affecting mitochondrial membrane permeability in a manner different from hydrocortisone. The inhibitory locus of the alkaloid is the nitrogen atom of the cyclic base. The alkaloids, but not the *N*-oxides, block impulse transmission across neuromuscular junctions, which explains the hyperacute toxicity of large doses. Pyrrolizidine alkaloids, which contain an esterified organic acid with two or more hydroxyl groups on adjacent carbon atoms, such as lasiocarpine, are capable of forming complexes with copper. The complexes were identified by a colour reaction in alkali, and by electrophoresis patterns. The toxicity of lasiocarpine, when injected into rats, is considerably reduced when the compound is complexed with copper.

(*b*) *Posthitis* (Regional Pastoral Laboratory, Armidale).—External and internal ulceration resolved in wethers treated by insertion of plastic tubes designed to keep the preputial orifice patent. However, many of the self-retaining tubes (70 per cent.) and of tubes held in place by a suture (35 per cent.) were lost over a period of three months. A 20 per cent. alcoholic solution of cetrimide or 10 per cent. copper sulphate ointment temporarily reduced incidence of early cases of internal ulceration, but chronic cases did not respond satisfactorily. Copper sulphate ointment, but not the cetrimide, was also effective in reducing incidence of external ulceration. A further experiment commenced to determine the prophylactic value of repeated testosterone implants.

(*c*) *Mycotic Dermatitis* (McMaster Laboratory).—The motile coccoid stage of *Dermatophilus dermatonomus* is responsible for migration of the organism and for transmission of the disease. A study of its physiology suggests that mycotic dermatitis may be transmitted naturally only in cool wet conditions and directly from sheep to sheep.

Despite the dry summer of 1957-58 a number of severe outbreaks of mycotic dermatitis was reported in weaners. In all cases they were associated with shearing and dipping. On two occasions, severe outbreaks were seen in very young lambs at marking, and one of them was associated with a high incidence of the disease in the ewes. Lambs dropped to comparable ewes virtually free of body lesions were themselves free of body lesions, but some had suspicious lesions of the face or ears. Further studies are being made on the transmission of the disease from infected ewes to their lambs. Parenteral treatment with antibiotics showed some promise.

(*d*) *Footrot*.—Studies on growth factors required by *Fusiformis nodosus* have shown that at least one essential factor is provided by keratin. *F. nodosus* produces an enzyme which attacks the junction of the prekeratin and prickle cell layers on the hoof. Histological studies have shown that *F. nodosus* is highly invasive but does not enter the prickle cell layer. In field observations footrot spread only in warm weather when a long dense mat of pasture was present. Long native pastures or short improved pastures, which dry rapidly, were not conducive to its spread, even after fairly heavy rain. Lesions tend to regress in dry conditions but do not always heal completely. Further studies are being made on the association of infection with *Strongyloides papillosus* infestation. Tests of two methods of treatment claimed to cure footrot without paring of the feet showed that neither was sufficiently effective.

Investigation of an outbreak of " scald ", which simulates early footrot, but does not show underrunning of the hard horn, revealed the presence of an organism which resembles *F. nodosus* morphologically. This organism was isolated and reproduced the condition on transference to the feet of a sheep. Smears from cases of " scald " can be confused with those from cases of true footrot but the clinical condition is quite distinct.

(*e*) *Foot Abscess.*—A selective medium was successful in indicating the approximate concentrations of *F. necrophorus* in suspensions of normal faeces to which different amounts of the culture had been added. This organism was not found in faeces from normal sheep.

(*f*) *Brucellosis of Sheep* (Animal Health Laboratory, Melbourne).—Experiments in which *Br. abortus* strain 19 was introduced into rams by various routes were concluded. Seminal vesicles could retain the infection when it had disappeared from other sites, including site of inoculation. It was noted that injection of strain 19 produced antibodies which fixed complement in the presence of *Br. ovis* antigen.

(*g*) *Experimental Pathology* (McMaster Laboratory). (i) *Pregnancy Toxaemia.*—Further studies of enzymic disturbances of metabolism of ewes with pregnancy toxaemia confirmed that the biochemical lesion was a failure of liver fatty acid metabolism. Hydrocortisone was shown to increase mitochondrial membrane permeability *in vitro,* allowing diffusion of soluble co-factors from mitochondria and thus inactivating nucleotide-dependent dehydrogenases. It is postulated that hydrocortisone regulates metabolism *in vivo* by this mechanism.

(ii) *Biochemical Effects of Parasitic Infestation.*—Studies on *Nippostrongylus muris* infestation concluded with the histochemical demonstration of large amounts of calcium in cells of the parasite gut wall. These cells are probably the source of calcium released during homogenization to uncouple oxidative phosphorylation in enzyme preparations from infested jejuna.

(iii) *Carbon Tetrachloride Poisoning.*—*In vitro* studies were completed on the action of carbon tetrachloride on enzyme systems. It was shown to accelerate " ageing " and this phenomenon was studied in relation to mitochondrial semi-permeability.

(iv) Ixodes holocyclus *Toxin.*—Investigations on the citric acid cycle of liver and brain mitochondria obtained from tick-infested animals showed that DPN-dependent substrate oxidations were inhibited and could be restored by addition of DPN to the test media. Oxidative phosphorylation coupled to DPN-dependent substrate oxidations was also impaired but could not be restored by the addition of DPN. The pink cuticular excretion of *Ixodes holocyclus* was found to precipitate from an aqueous solution as a dark blue acid-soluble lead salt.

(*h*) *Urinary Calculi* (Sheep Biology Laboratory, Prospect).—Work started on the renal physiology of sheep with emphasis on those aspects thought to be concerned with formation of urinary calculi and development of posthitis in wethers.

18. Internal Parasites.

(Division of Animal Health and Production.)

(*a*) *Studies on Anthelmintics.* (i) *At McMaster Laboratory, Sydney.*—Some batches of commercial phenothiazine had poor anthelmintic activity, probably owing to incomplete conversion of diphenylamine to thiodiphenylamine (phenothiazine).

Phenothiazine was excreted over a period of four weeks when sheep were deprived of water for 24 hours before and after administration. Excretion is usually complete within one week when water is not withheld.

Further studies on Bayer " L13/59 " (" Dipterex ", " Neguvon ") confirmed that its effects against *Haemonchus contortus* may be variable. It was not effective against *Trichostrongylus colubriformis* unless injected or swallowed into the abomasum. Subcutaneous injection was effective against *H. contortus,* but not against *T. colubriformis.* Activity of Bayer " 21/199 " (" Muscatox ", " Asuntol ") was not affected by concurrent administration of 5 g. sodium thiosulphate. At 0.5 g./100 lb. body weight, concurrent adminstration of sodium thiosulphate had slight protective action against toxicity, but at 0.75-2.0 g./100 lb. body weight, even 10 g. sodium thiosulphate did not prevent death. Mixtures of these two organic phosphorus compounds showed no enhanced anthelmintic activity.

Further studies on bephenium compounds suggested that hydroxynaphthoate is more effective than embonate against *T. colubriformis,* but neither is effective against this species unless injected or swallowed into the abomasum. When the dose of the embonate exceeded 10-20 g./100 lb. body weight toxic effects occurred.

Further work on butyl-*N*-phenyl thiocarbamate and 3-3′-diethyl thiocarbocyanine showed that anthelmintic activity in sheep was not of a high order. *N*-acetyl phenothiazine (10 g.) into the rumen was ineffective against *H. contortus* and *T. colubriformis.* Intramuscular injection of 1-4 ml. carbon tetrachloride was only moderately active against *H. contortus.* 1,8-Dihydroxyanthraquinone (2 g.) was ineffective against *T. colubriformis* when injected into the abomasum.

Daily doses of 1 ml. safrole were ineffective against *H. contortus* and *T. colubriformis,* but 5 ml. doses daily for seven to fourteen days reduced egg counts in two of four sheep. A dose of 0.5 g. aloes in ethyl alcohol, injected into the rumen, was ineffective against *H. contortus* and *T. colubriformis.* Administration of 10 g. piperazine hexahydrate in drinking water over 24 hr. did not affect *H. contortus* or *T. colubriformis.* Sheep did not readily eat feed containing one part " hygromycin " in five parts of their normal ration, but nevertheless showed a gradual decline in worm egg counts over eight weeks. *H. contortus* and *Oe. columbianum* were affected more than *T. colubriformis.* When nicotine sulphate was injected into the rumen it was not effective against *Moniezia* spp. Sodium arsenite, similarly administered, was effective in three of five sheep. These compounds must be swallowed into the abomasum to ensure a high degree of efficiency. 4,6-Bis(benzothiazole-2-thio)-1,3-dinitrobenzene (2g./kg. body weight) was not effective against oxyurids in mice.

A mixture of 1,8-dihydroxyanthraquinone and carbon tetrachloride did not produce untoward effects when dosed to ten ewes at pasture.

In a field trial, fine-particle phenothiazine (90 per cent. less than 10μ) and bephenium embonate were very effective against mature *Nematodirus* spp., especially when administered after swabbing over the tongue with a solution of copper sulphate. " Neguvon " was less effective. A mixture of phenothiazine and bephenium embonate appeared slightly more effective than either compound alone. Anthelmintic efficiency against other species present, chiefly *Ostertagia* spp. and *Trichostrongylus* spp., was of a generally high order for phenothiazine and was not influenced by closure of the oesophageal groove. " Neguvon " was ineffective unless swallowed into the abomasum. Bephenium embonate had only slight activity unless swallowed into the abomasum.

(ii) *At Regional Pastoral Laboratory, Armidale.*—*Phenothiazine-salt lick.*—Breeding ewes grazed at four and eight per acre on a sown pasture were provided with a 1 : 12 mixture of phenothiazine and salt; control groups had access to salt. In spring, worm egg counts were higher in the ewes at the heavier stocking rate and in this group the provision of phenothiazine reduced egg counts by more than half during October and November. There was also a lower level of worm infestation in lambs from ewes which received phenothiazine.

" Neguvon " (Bayer " L13/59 ").—A dose rate of 2.5 g. per 100 lb. body weight was safe in lambs, weaners, ewes, and wethers, as well as in pregnant ewes drenched four weeks and again at two weeks before lambing: 5.0 g. per 100 lb. body weight frequently produced toxic signs especially if given after swabbing with a 10 per cent. copper sulphate solution. In wethers, 2.8 g. per 100 lb.

was highly effective in reducing egg counts of *Haemonchus contortus* and was comparable in this respect to a 10 g. dose of phenothiazine.

(*b*) *Effect of Nutritional Level on Infestation* (McMaster Laboratory).—When worm-free lambs were maintained on high and low planes of nutrition for two and a half months and were then given a single dose of *T. colubriformis* larvae, the level of nutrition did not greatly influence establishment of infestation. However, severity and persistence of initial infestations showed pronounced differences. In the high-plane group all ten sheep survived and the worm egg counts declined to very low levels in six within two months. In the low-plane group all developed heavy infestations and five died. In similar lambs given repeated doses of larvae (200 daily for 50 days) the severity of the infestations was less than in sheep given single doses, and degree of infestation in the high-plane group was very much less than that in the low-plane group, in which five of ten sheep died. When challenge doses of larvae were given four months after the initial dose, most of the sheep on the high-plane ration were relatively resistant while most of those on the low plane were highly susceptible. Although egg counts did not increase in sheep on the high plane, rates of weight gain decreased after the challenge dose.

(*c*) *Epidemiology*.—In epidemiological studies in east Gippsland, Victoria, worm egg counts of *Ostertagia* spp. and *Trichostronglus* spp. in lambs born in spring showed peaks in early summer and again in autumn but were low thereafter. Numbers of *Chabertia ovina* and *Oesophagostomum venulosum* showed a brief peak in late summer and were at maximum levels throughout the winter months.

Monthly faecal examinations of cattle in the far Southern Tablelands region of New South Wales revealed heavy infestations with *Ostertagia* spp. and *Cooperia* spp. *Fasciola hepatica* was also common.

A technique, developed for recovery and counting of infective larvae in rumen contents, was applied during an outbreak of haemonchosis. The intake of larvae and their numbers in pasture samples were related to rainfall and to the sequence of events in self-cure. Variations in larval intake between sheep suggested differences in grazing behaviour.

(*d*) *Resistance and Immunity to Nematodes*.—Serological reactions taking place during self-cure of sheep infested with *H. contortus* were investigated by complement-fixation, haemagglutination, and the Ouchterlony agar-diffusion precipitin techniques. A test to detect incomplete antibodies was applied to certain sera. The main antigenic stimulus at self-cure was derived from substances released from larvae during the third ecdysis. Absorption tests showed that antibodies which react in the complement fixation test and in the haemagglutination test were distinct.

Stimulation of immunity by injection of exsheathed larvae or by oral administration of irradiated larvae is under investigation.

(*e*) *Exsheathment of Nematode Larvae*.—Exsheathing fluid contains a protein and a dialysable cofactor. Dialysed fluid is inactive, but activity is restored by Mn^{++} or Mg^{++}. The Q_{10}, about 1.6, is in the range appropriate to an enzyme catalysed reaction. Activity is suppressed by addition of iodoacetate. Crude solutions of exsheathing fluid contain antigenic substances, some of which are apparently specific. When larvae release exsheathing fluid in the presence of exsheathing fluid antiserum, precipitates form at the excretory pore which is probably the site from which the fluid is released.

The adult cuticle of *Nippostrongylus muris* lifts off the hypodermis about 85 hr. after infestation. The onset of this moult is shown by the formation of blisters as the cuticle expands. Male larvae commonly moult 6-9 hr. after formation of the bursal rays has been completed. If ligated in the mid point of the body immediately the development of the bursal rays has terminated, they moult in front of the ligature but not behind it. If ligation is delayed several hours, larvae moult behind as well as in front of the ligature.

(*f*) *Chemical Studies on Anthelmintics*.—Substituted phenothiazines have been synthesized by selective reduction of a nitro group of the corresponding 2,2′-dinitrodiphenyl sulphides in the presence of alkali. Phenothiazines were also prepared by action of sodium sulphide on *o*-halonitrobenzenes in a high boiling solvent.

Excretion of phenothiazine by sheep was investigated. Phenothiazine of fine particle size was more readily retained than coarser material, but very fine particles were not absorbed as rapidly as expected. Restriction of water consumed by an animal, before and after drenching, prolonged the rate of excretion of phenothiazine in both urine and faeces.

(*g*) *Liver Fluke*.—Further studies were made on the bionomics of *Simlimnea subaquatilis*. The optimum temperature for the reproduction of these snails is 24-26° C. They can produce egg masses at the usual temperatures found in their habitats during winter but hatching is delayed until the spring. They can aestivate in mud for at least eleven months under field or laboratory conditions.

In vitro experiments with copper sulphate, copper pentachlorphenate, sodium pentachlorphenate, zinc sulphate, and zinc pentachlorphenate, showed that copper sulphate and copper pentachlorphenate were the most lethal to snails and their egg masses. Both the delta and gamma isomers of BHC were inefficient.

Bionomics of intermediate stages of *Fasciola hepatica* were studied. Viability and vigour of the miracidia determine the success of artificial infestation rather than individual susceptibility of snails. Hatching time, preinfestation period, and environmental conditions influence the viability of miracidia. Previous infestation with other trematode intermediate stages does not influence the susceptibility of snails to *F. hepatica*. A satisfactory method was evolved of harvesting and testing the viability of cercariae. Cercariae resist currently used molluscicides applied at recommended concentrations.

Studies continued on parenteral administration of carbon tetrachloride for treatment of fluke infestation. Cattle require a dose rate of 10 ml. per 200 lb. live weight for effective intramuscular therapy.

Abattoir surveys have shown that incidence of fascioliasis in sheep in New South Wales averaged 13.8 per cent. The average incidence in 46,771 cattle was about 50 per cent.; dairy cattle (87.9 per cent.) showed a much higher incidence than beef cattle (44.6 per cent.). The highest incidence for both sheep and cattle was found in animals from the tablelands and coast.

(*h*) *Pathology of Intestinal Nematode Infestations*.—There was no change in rates of absorption of glucose and histidine from the entire small intestine of rats infested with *Nippostrongylus muris*. Perfusion experiments suggest that absorption of glucose from the infested part of the jejunum is markedly reduced. Efflux of sodium as NaCl labelled with ^{24}Na from the same section of the gut is reduced by about one-half to one-third, while influx is unchanged by infestation. This reduced efflux explains the net influx of sodium, water, and chloride occurring when the infested jejunum is perfused with isotonic saline. Accumulation of intestinal water, sometimes accompanied by diarrhoea, does not affect the percentage of water in fat-free eviscerated carcasses. Failure of infested rats to gain weight at the same rate as normal animals is in part due to a loss of fat. Although infestation does not affect rate of gastric emptying measured with ^{57}Cr, it reduces rate of passage through the infested section of gut. There is probably a faster movement of ingesta through the lower ileum.

In trichostrongylosis of sheep there is a slight thinning of the muscularis externa of the infested small intestine in marked contrast with the jejunum of rats which is thickened in nippostrongylosis.

19. External Parasites.

(Division of Animal Health and Production.)

(*a*) *Ecology of External Parasites* (McMaster Laboratory).—Additional information on requirements for egg development of *Damalinia equi* and for pupal development of *Melophagus evinus* was obtained. Under hot climatic conditions the microclimate on the legs and scrotum of a sheep remain favorable for development of *Linogathus pedalis* whereas it is unfavorable on the body. Influence of microclimate on the reproductive physiology of lice is being studied.

(*b*) Psorergates ovis.—Field trials showed that a single dipping in 0.2 per cent. arsenic gave control of *Psorergates ovis* (itch mite) comparable to that by lime sulphur. Dipping of sheep in a formulation of delta isomer of BHC failed to control itch mite. Systemic use of aldrin, diazinon, and kerlan also failed. Patch tests have shown a kill of itch mites with 0.1 per cent. kelthane and 1 per cent. kerlan. Attention is being directed to control of itch mite with tip sprays. When examined two months after treatment, mites appeared to have been eradicated from a single sheep tip sprayed with 1 per cent. arsenic.

20. Sheep Blowflies.

(Division of Entomology.)

(*a*) *Ecological Studies*.—In a broad study of regional and seasonal incidence of sheep blowflies, observations were made on overwintering of several species in the Australian Capital Territory. No pupae of *Chrysomyia rufifacies* occurring naturally in carcasses in autumn have yet been found to survive the Canberra winter. This species may repopulate the Canberra area every year from milder regions. Maternal-induced diapause—the mechanism by which *Lucilia sericata* produces overwintering stock—has also received further study. Experience with *L. sericata* in warm insectaries pointed to seasonal variation in light as an important influence in the induction of diapause.

Further studies were carried out on production of blowfly species in carcasses of various animals.

(*b*) *Insecticide Trials*.—Using the larval implant technique, small-scale tests were made on " Sevin " (1-naphthyl *N*-methylcarbamate) and two organic phosphorus insecticides, " Roger 40 " and " Dicapthon ", for prevention of sheep blowfly strike. " Sevin " permitted some larvae to survive eight days after treatment, and both this and " Roger 40 " allowed larvae to survive in most implants 29 days after treatment. " Dicapthon " still afforded a high degree of protection 78 days after treatment.

Field trials arranged in collaboration with the Queensland Department of Agriculture and Stock failed through non-occurrence of a natural strike wave.

(*c*) *Diazinon Oviposition Deterrent for* Lucilia cuprina.—Indirect evidence is available that gravid females of *Lucilia cuprina* are deterred from ovipositing by the presence of diazinon on fleece. This leads to oviposition selectively on any areas missed during application. Direct evidence for this process has now been obtained from insectary trials, and these underline need for thorough application of the insecticide.

21. Other Sheep Investigations.

(Division of Animal Health and Production.)

Pasture Intake and Digestibility Studies (Regional Pastoral Laboratory, Armidale).—Data are accumulating on the relationship between pasture intake and productive performance of fine-wool Merinos by means of the chromic oxide marker technique. Digestibility trials on native, improved native, and sown pastures allowed tentative equations for estimation of the digestibility of grazed pasture to be calculated from the nitrogen content of sheep faeces. Accuracy of predictions should steadily improve as investigations are extended to a wider range of species and stages of growth. The possibility is under study of developing equations based on fibre content more satisfactory for low-quality roughages.

22. Climate Physiology of Sheep.

(Division of Animal Health and Production.)

(*a*) *Equipment for Bioclimatology Research* (Sheep Biology Laboratory, Prospect).—The special climate chambers have been principally devoted to work on wool growth, but other short-term projects have been undertaken. Control of air movement (to stimulate wind) has previously been achieved by the use of a variable-pitch aircraft propeller in a wind tunnel, giving a range of air movement from 100 to 1,500 ft./min. This wind tunnel will be used to study heat transmission through the skin of shorn sheep exposed to wind and rain.

(*b*) *Seasonal Variation in Wool Growth*.—Sheep grow wool faster in summer than in winter even with uniform feed intake. The current experiment is planned to study, under controlled conditions, the relative importance of day length and ambient temperature in causing this seasonal variation. The experimental animals are Merino and Southdown ewes. In planning this experiment the possibility was considered that seasonal variation might be the modern equivalent of the archaic pattern of shedding and regrowth. Slow growth in winter might be equivalent to follicular quiescence preceding shedding in spring. Rapid growth in summer would correspond with rapid regrowth of the archaic fleece after shedding. In spring all groups in this experiment shed hair from the feet, and wool from just above the feet; Southdowns and Merinos were alike in this respect. This shedding was too near to the start of the experiment to be influenced by the various treatments. It remains to be seen whether shedding can be affected by climate, and whether it is related to growth of wool on the tattooed patches. The experiment is not yet far enough advanced to decide whether temperature or light controls the seasonal rhythm of wool growth.

In other experiments on wool growth endocrinology, sheep were maintained on constant feed intake throughout the year under fairly constant temperature conditions. These sheep failed to show normal seasonal variation in wool growth. This observation suggests that ambient temperature is probably a more important cause of seasonal trend than daylight duration.

(*c*) *Seasonal Variation in Reproduction*.—The breeding season of Merino and Southdown ewes is being studied by mating with vasectomized rams and measurement of vaginal volume to detect oestrus. Daily measurements of apparent vaginal volumes have been made during several oestrus cycles. The volume stays constant except on the day of oestrus when it rises considerably. Daily measurements during anoestrus showed no variation in volume except towards the end of anoestrus. During the period fourteen to seventeen days prior to the first marking by the ram at the beginning of the breeding season, there was a rise in vaginal volume in some sheep, suggesting occurrence of ovulation without oestrus. Vaginal volumes are greater during the breeding season than during anoestrus, and diminish as anoestrus approaches. Changes in apparent vaginal volume during the breeding season run parallel to changes in fertility observed in the field. This method may reflect the physiological state of the reproductive tract, and thus have some advantage over the " all or none " response to the vasectomized ram.

(*d*) *Cold Stress in Sheep.*—Study of cold stress is being made along several lines. Freshly shorn sheep have been exposed to cold conditions and effects on heart rate, and rectal and skin temperatures measured. Even a slight wind of 7 m.p.h. was found to have a cooling effect equivalent to a drop of 20° F. in environmental temperature; rain at the rate of ⅓ in. per hour was equivalent to dropping the temperature by about 5° F. Some protection against cold was obtained by shearing with the New Zealand snow comb, which leaves about ½ in. of wool. Exposure to cold was found to produce a rapid increase in skin thickness even when the sheep carried fleeces 1-2 in. long; a similar increase has previously been recorded in sheep, under natural conditions, after shearing.

(*e*) *Sweating in Sheep.*—The total water loss from the skin was measured in five breeds of sheep under mild and hot conditions. In addition, measurements were made on four mutant Merino sheep (" gog " mutants) congenitally devoid of sweat glands. Using these values as corrections, the actual secretion of water from sweat glands of normal sheep could be calculated. No real difference between breeds was found, and even under hot conditions, the sweating rate was very low (about 33 g./m^2/hr.). These observations emphasize the importance of panting as the cooling mechanism of sheep.

VIII. CATTLE.

1. GENERAL.

Cattle grazing is complementary to the raising of sheep in many of Australia's abundant pastoral areas, and production from cattle is second only to that from sheep in importance to the rural economy. The Organization aims to apply research to benefit the cattle industry in every way possible.

Current investigation includes: elimination of loss from disease in both beef and dairy cattle; improvement of nutrition by development of sown pastures; better management of natural pasture; and development of systems of breeding designed to evolve more productive beef and dairy types for northern Australian conditions.

The Organization's work on cattle problems is carried out chiefly by the Division of Animal Health and Production, at the Animal Health Laboratory in Melbourne, the National Cattle Breeding Station at " Belmont ", near Rockhampton, Queensland, and the Veterinary Parasitology Laboratory in Brisbane, Queensland (see Sections 2, 3, 4, 6, 7, and 8 of this Chapter). The Division of Entomology has been concerned with work on cattle tick (see Section 5 of this Chapter). The work of the Division of Plant Industry on pastures is also of great importance to the cattle industry (see Chapter III). The work of the Animal Genetics Section on beef cattle is described in Section 9 of this Chapter.

2. CATTLE DISEASES.

(Division of Animal Health and Production.)

(*a*) *Pleuropneumonia of Cattle* (Animal Health Laboratory, Melbourne).—Research was concentrated on vaccination, to determine whether " egg vaccine " (reconstituted lyophilized homogenate of chick embryos succumbing to infection with *Mycoplasma mycoides* strain " V5 ") was superior to standard liquid " V5 " culture vaccine, administered by tail-tip innoculation. Vaccines showed lower efficiency against challenge by intense and prolonged exposure to a high density of acute cases than by a single but massive exposure to aerosolized culture. Egg vaccine was more efficient than liquid vaccine, with no evidence of attentuation or lowered efficiency between 5th and 52nd passage of egg vaccine. With subcutaneous challenge, efficiency was almost absolute one month after vaccination, when complement fixation reactions were at their peak, but it had decreased 20-30 per cent. five-six months later when CF reactions had become negative; at that time protection was expressed mainly as early retrogression of lesions after they had developed to some extent.

Discharge of the causal organism in nasal mucus or saliva was commonly observed during the acute phase of the disease. Instances of typical pleuropneumonia occurred in young calves in the infected herd and this was accompanied by polyarthritis.

Lyophilized egg vaccine retained almost complete viability at 4° C. for more than twelve months, but at high temperatures (45° C., 113° F.) viability decreased 90 per cent. within 24 hours. Egg vaccine reconstituted for use was sensitive to high temperatures, and viability decreased 99 per cent. within an hour at 113° F.

Studies on the nutritional requirements and immunochemistry of *M. mycoides* were continued. A polysaccharide isolated from *Actinobacillus lignieresi* " S40 ", and serologically related to the *M. mycoides* polysaccharide reported previously, also contains galactose as a major constituent, but considerably more lipid. No evidence was obtained that cow-pox infection leads to false-positive CF reactions when the standard C.S.I.R.O. test is applied.

This year the equivalent of 1,500,000 " syringe doses " of " V5 " liquid culture vaccine were issued. Complement fixation antigen sufficient to test 18,000 cattle was supplied *gratis* to testing authorities in Australia. Gifts were made to Kenya (23,000 tests) and Assam (1,600 tests) as a contribution to disease control within the British Commonwealth, and to the Philippines (5,300 tests) to assist importation of cattle from Australia.

(*b*) *Infertility in Cattle.*—There is now further evidence that vibriosis is a major cause of infertility in dairy herds, and work was concentrated on developing and evaluating procedures which, under Australian conditions, will facilitate the establishment of a herd diagnosis. Vaginal mucus agglutination (VMA) is the most practicable, sensitive, and accurate diagnostic test. It is proposed to standardize this test, and produce and distribute a satisfactory antigen at low cost to diagnostic laboratories in the several States.

Testing bulls for freedom from vibriosis is important at artificial insemination (A.I.) centres in Australia. Mating test heifers has shown that cultural examination of vaginal mucus after natural service of three or more heifers with an infected bull will not always demonstrate infection in the male.

(*c*) *Virus Diseases of Cattle.*—A Virology Section has been established to study virus diseases of livestock. Diseases of cattle will be investigated first, especially those affecting the alimentary or respiratory tract. Tissue cell cultures have been established for this work. Calves born in Victoria have been found to carry an organism of the psittacosis-lymphogranuloma group in the intestine. This infection produces no ill effects, but knowledge of its presence is important for later work on pathogenic viruses affecting the alimentary tract. Towards the end of 1958 a disease resembling " epizootic diarrhoea of cattle " or " winter dysentery " was diagnosed in Victoria on clinical evidence and preliminary experiments were undertaken on this disease.

(*d*) *Bloat* (Regional Pastoral Laboratory, Armidale).—" Terramycin " (oxytetracycline hydrochloride), given each week by ruminal injection (200 mg.), reduced evidence of bloat in cattle on clover-rich pasture and there were no deaths. One of ten animals died in the control group. Pasture conditions were conducive to mild but consistent bloating in the untreated cattle.

3. INTERNAL PARASITES.

(Division of Animal Health and Production.)

Investigations concerned with parasitic gastro-enteritis carried out by the Veterinary Parasitology Laboratory, Yeerongpilly, Queensland, were:

(*a*) *Techniques.*—An improved technique for egg counts has been developed which will detect counts as low as one egg in 2 g of faeces. Faecal cultures for larval differentiation have been improved by using vermiculite, a powdered mica derivative, in the cultures in lieu of sterile dry cattle faeces.

(*b*) *Studies on the Nodular Worm,* Oesophagostomum radiatum.—Reactions of animals, reared worm-free, and experimentally infested with single, spaced, and daily doses of larvae, have been closely observed. *Oe. radiatum* is a well-adapted parasite and almost all calves can be infested readily with it. The most severe pathogenic effects were exerted by immature fifth stage parasites. Loss of appetite may be a major factor in the pathogenesis of the disease, but feed utilization by infested calves was also impaired. Studies have commenced on the gross pathology and histopathology of this disease.

(*c*) *Serological Response in Calves.*—Haemagglutination and complement fixation tests were performed on 2,337 serum samples drawn weekly from 102 calves in six different experimental groups. Some of these groups were calves exposed to natural infestations of mixed species and others of animals reared worm-free and infested with *Oe. radiatum.*

No substantial difference in titre was found in surviving animals compared with those dying after exposure to natural mixed infestations; some calves which died from helminthosis had developed high haemagglutination and complement fixation titres. Circulating antibodies demonstrated by these haemagglutination and complement fixation tests are not responsible for the development of resistance, their presence implying only that the host has experienced worm infestation.

(*d*) *Ecology of Preparasitic Stage in the Pasture.* (i) *Experimental Pat Exposure.*—The effect of rainfall on migration from the pat and longevity of larvae in the pat and on the pasture was confirmed. During the period of high rainfall experienced in 1958, longevity of larvae on the pasture was increased from six to nine weeks, and the life of the pat as a source of larvae decreased from six to four months. The production of larvae from pats was correlated with average monthly rainfall, those months with highest rainfall giving greatest larval production. Peaks of larval production from experimental pats agreed with those observed on natural pasture.

(ii) *Larval Population Fluctuation on Natural Calf Pasture.*—Although rainfall conditions in 1957 and 1958 were different and pasture conditions differed accordingly, peaks of larval abundance occurred during the same periods in both years. These periods corresponded with months of highest rainfall, namely, February-March, June-July, and November-December.

Intensity of larval populations were lower during 1958 due to dilution by abundant pasture. This caused low pasture counts, especially with such species as *Haemonchus* and *Oesophagostomum.*

(iii) *Observations on Calves Grazing Natural Pasture.*—Under good pasture conditions low larval populations may be dangerous to susceptible animals, presumably owing to an increased intake of pasture. In 1957 and 1958 susceptible animals, grazing during peak periods of larval abundance, were rapidly overwhelmed. Periods between peaks appear relatively safe and permit susceptible animals, introduced to pastures at these times, to build up resistance to withstand periods of high larval prevalence. Calves introduced to pasture during these troughs in larval abundance develop resistance more readily during years of adequate nutrition than when pastures are poor.

(*e*) *Effect of Temperature on Development of Preparasitic Stages.*—In experiments with *Oe. radiatum,* only a small percentage of eggs hatched at 105° F. and larvae failed to develop; at 60° F. a good hatch was obtained and larvae became infective in 21 days. With *Cooperia* spp. (*C. punctata* and *C. pectinata*), hatching was successful at 105° F., and the infective stage was reached in four days; at 60° F., the infective stage was not attained until fifteen days. All eggs of *Oestertagia ostertagi* were killed at 105° F., whereas at 60° F. they hatched and larvae became infective in ten days. Eggs of *Trichostrongylus axei* hatched at 105° F. and at 60° F., and infective larvae were present in eleven days.

(*f*) *Copper in the Host-Helminth Relationship.*—The pH values in segments of the gastro-intestinal tract indicated that only in the ileum, caecum, and colon are the concentrations of hydroxyl ions likely to limit the concentration of copper ions, thereby reducing the copper available for diffusion into helminths parasitizing these habitats. This was confirmed by the addition of copper sulphate to clarified caecal fluid (pH 7.1), in which the concentration of soluble copper was limited to approximately 0.10 mg. Cu/100 ml. When copper sulphate was added to duodenal contents (pH 5.96), all added copper was recovered in solution within the examined limits of 0.080-0.240 mg. Cu/100 ml.

(*g*) Fasciola hepatica.—The economic importance, epidemiology, and control of fascioliasis are being studied in Queensland cattle. Investigations have been confined to the Maleny district, where 80 per cent. of properties were infested. The intermediate host is *Simlimnea subaquatilis.* On the coastal plain snail populations may be drastically reduced during December-March; this could be a temperature effect.

(*h*) *Anthelmintics.*—" Neguvon " (Bayer " L13/59 ") was effective against *O. ostertagi* in five calves at dose rates of 2.5 and 5 g. per 100 lb. body weight. Trials with high and low doses of " Neguvon " in naturally infested calves are in progress to determine the effect of regular dosing on helminth populations and development of resistance. The experiment should also yield information on toxic effects from repeated treatments. " Nexion 1384 ", another organic phosphate compound, was efficient against *Haemonchus placei* in three calves at dose rates of 5 and 10 g. per 100 lb. body weight but its effect was erratic on *Cooperia* spp. (ten calves) and *Oe. radiatum* (four calves). At the higher dose rate it was ineffective against *T. axei* (two calves). The lower dose rate gave good results against *O. ostertagi* (one calf only).

Bephenium hydroxy naphthoate, at a dose rate of 5 g. per 100 lb. body weight, was ineffective against *H. placei* and *Bunostomum phlebotomum* and moderately effective against *Cooperia* spp. At 10 g. per 100 lb. body weight this compound proved highly effective against *H. placei* (two calves), *Cooperia* spp. (ten calves), *Oe. radiatum* (three calves), and *T. axei* (one calf).

In limited trials, 1,8-dihydroxyanthraquinone (100 mg. per kg. body weight), Bayer " L13/59 " (100 mg. per kg. body weight), Bayer " 21/199 " (50 mg. per kg. body weight), and Dow " ET-57 " (250 mg. per kg. body weight) were ineffective against *Fasciola hepatica* in guinea pigs.

4. CATTLE TICK.

(Division of Animal Health and Production.)

Investigations have continued at the Veterinary Parasitology Laboratory, Yeerongpilly, on cattle tick and tick fever.

(*a*) *Tick Fever.*—Studies on the life history of *Babesia bigemina* in the cattle tick *Boophilus microplus* have shown a very low infection rate in larvae of *B. microplus*, and, although considerable material was examined, no intermediate stages in the tick have yet been identified. Liver biopsy and skin samples taken at different intervals after application of infective larvae have been negative for intermediate forms in the vertebrate cycle. Parasitaemia was seen seven days after application of larvae and larvae appear to transmit the infective stage to cattle. Cases of cerebral babesiosis (*B. argentina*) were encountered in experimental tick transmissions.

Studies in the epidemiology of tick fever concerned detection of carrier animals. A satisfactory thick blood smear technique was developed which allows the species of *Babesia* to be readily differentiated. A complement fixation test was developed for diagnosis of *B. bigemina* and appears to be specific. Preparation is being attempted of a highly sensitive *B. bigemina* antigen, requiring development of strains which will quietly invade a high percentage of red cells.

(*b*) *Studies on the Pigment in the Eggs and Larvae of* Boophilus microplus.—The prosthetic group of the haemoprotein occurring in eggs of *B. microplus* was found to be protohaem, and is therefore identical with that of bovine haemoglobin. The physiological role of the haemoprotein was investigated. No respiratory function could be demonstrated for the pigment. The protein moiety of the haemoprotein is utilized as a food reserve by developing larvae while the discarded haematin remains as an amorphous solid deposit in the larval gut.

(*c*) *Parthenogenetic Development of* Haemaphysalis bispinosa.—*H. bispinosa* was shown to reproduce by obligatory parthenogenesis. Male ticks were scarce in both natural and experimental infestations, occurring in the approximate ratio of one male to 400 females. No spermatazoa were produced by male ticks. Rates of development of non-parasitic stages were examined under controlled conditions of temperature and humidity.

(*d*) *Cytology of Australian Ixodidae.*—Chromosomes were studied of ten species of ixodid ticks. The basic chromosome number of the family appears to be $2n$—21 (male), 22 (female). Diploid numbers of 19 (male), 20 (female) are featured by *Amblyomma triguttatum* and *Aponomma decorosum* and are associated with the presence of giant sex chromosomes. *H. bispinosa* is triploid, probably as a consequence of the evolution of a parthenogenetic mode of reproduction.

(*e*) *Studies on Tick Taxonomy.*—Previous studies on *Aponomma* and *Amblyomma* have been extended to the genus *Ixodes*. Nineteen species were recognized, two regarded as new, and three others recognized in Australia for the first time. Five species were all similar to *I. holocyclus* morphologically. This raises the question whether *I. holocyclus* is the only species associated with tick paralysis. The material under examination indicates that *I. holocyclus* may not extend further south than about Milton, New South Wales. If so, tick paralysis in New South Wales south of Milton, and in Victoria and Tasmania, could be associated with the species occurring in these areas, either *I. hirsti* Hassall or *I. cornuata* n.sp., or perhaps with both.

5. BIOLOGY AND CONTROL OF CATTLE TICK.

(Division of Entomology.)

There has been no marked change in the pattern of cattle tick resistances to acaricides. Organic phosphorus compounds are finding increased use, particularly against cattle ticks resistant to chlorinated hydrocarbons. No ticks are known resistant to organic phosphorus compounds.

Pasture spelling trials at Amberley and Townsville, and the observations on tick survival in north Queensland, have continued.

(*a*) *Acaricide Resistance.* (i) *DDT Resistance.*—Four more strains of cattle tick from Queensland are now known to exhibit DDT resistance varying in degree from slight to moderately high.

(ii) *DDT Susceptibility of New South Wales Ticks.*—Fourteen strains of cattle tick from the Kyogle-Woodenbong area of northern New South Wales—where the 1956-57 campaign of eradication failed—have now been investigated, but none found to exhibit DDT resistance.

(iii) *Glutathione in Tick Embryos.*—Marked fluctuations occur in the glutathione content of tick embryos according to age, both in arsenic-susceptible and in arsenic-resistant cattle ticks.

(*b*) *Factors Influencing Dipping Fluid Toxicity.* (i) *Loss of Toxicity of Bayer "21/199".*—The toxicity of Bayer "21/199" in dipping vats declines as the fluid ages, and as contamination increases from dirt and cattle dung. Measured amounts of soil and dung were added at fortnightly intervals to a dipping vat charged with 0.05 per cent. Bayer "21/199". The toxicity of the fluid to ticks declined, and the deposits of Bayer "21/199" left on cattle hair showed a marked fall.

(ii) *Gamma BHC Depletion.*—A further attempt was made to determine the end products of breakdown of gamma-BHC in a sample where the gamma-BHC had lost 4-5 atoms of chlorine. The chlorine split from the BHC was detected as chloride and, using chromatographic methods, an organic chlorine breakdown product—as yet unidentified—was separated.

(*c*) *Field Testing of Chemicals Acaricides.* (i) *Mixtures of Acaricides in Dipping Vats.*—Observations were made on a number of dipping vats containing mixtures of DDT and an organic phosphorus compound. Use of these mixtures appears to have advantages over use of either of their components.

(ii) *Fluoro-compounds as Acaricides.*—Fluorinated compounds were tested as acaricides, but the dosage required to kill ticks was too close to that toxic for cattle.

(iii) *Screening Chemicals by Spraying Small Areas on Cattle.*—A number of chemicals were screened as acaricides by spraying approximately half the escutcheon of tick-infested cattle with a small CO_2-operated spray, leaving the remainder of the escutcheon untreated for comparison.

(iv) *Systemic Effect of Sprays.*—Spraying with Bayer "21/199" was reported overseas to produce systemic effects on ectoparasites on unsprayed areas. Beef dripping and lanoline saturated with a high concentration of Bayer "21/199" were applied by felt-padded belts to tick-infested cattle. No systemic effect was detected on ticks in areas not in contact with the belts.

(*d*) *Inefficacy of Sulphur Feeding for Cattle Tick Control.*—Sulphur feeding is frequently claimed to reduce cattle tick infestations. The numbers of engorged ticks falling from treated and untreated animals were compared, but feeding with sulphur produced no reduction in ticks.

(*e*) *Pasture Spelling Experiments.* (i) *Small Experiment at Amberley.*—Following reversal of treatments in experimental paddocks, tick numbers increased on the herd continuously occupying a single paddock, but decreased on the herd now moved periodically into spelled pasture.

(ii) *Large-scale Experiment.*—In the large-scale pasture spelling trial near Townsville, a spray race was installed and gave more effective treatment than the dip previously used. Freshly sprayed cattle, moved to a spelled pasture in September, were lightly infested in January—compared with a herd dipped at 7-8 week intervals and kept continuously in one paddock.

(iii) *Experiments at Ingham.*—Grants made by the United Graziers' Association of Queensland and the Australian Meat Board permitted the leasing of a 400 acre property near Ingham for study of pasture spelling and strategic dipping in the wet tropics. Fencing and other necessary improvements have been installed, 70 cattle purchased, and routine counts of tick numbers commenced.

(*f*) *Biology and Ecology of the Cattle Tick.* (i) *Survival of Non-parasitic Stages.*—To study pasture spelling and strategic dipping observations continued on tick survival near Charters Towers (rainfall 23 in.), Townsville (40 in.), and Ingham (85 in.). The longest survivals (period from fall of parent tick to death of last larval progeny) at Charters Towers and Townsville were 22 and 19 weeks respectively. Dry conditions between August and December were particularly unfavorable to survival on the sites selected. At Ingham survival periods ranged from twelve weeks for the progeny of single ticks exposed in November and December to 27 weeks for the progeny of ticks exposed in batches between late March and early June.

(ii) *Attachability of Aged Tick Larvae.*—Larvae are capable of engorging on cattle when gathered from pasture 10, 11, and 13 weeks after hatching there.

6. INVESTIGATIONS WITH DAIRY CATTLE.

(Division of Animal Health and Production.)

To provide animals for crossbreeding with European dairy types (*Bos taurus*) for study of adaptability to tropical conditions, a small consignment of dairy strains of Zebu cattle (*B. indicus*) was imported into Australia in 1954. Activities are concentrated at McMaster Field Station, where the following herds are maintained and related studies are in progress:—

(*a*) *Sindi and Sahiwal Cattle.*—The nucleus herds now comprise:—Sindis—Five males, nine females; Sahiwals—Three males, six females.

(*b*) *Zebu-cross Dairy Herd.*—A further eighteen Jersey heifers were obtained during the year. Culling for production in the Jersey dams continued at a high level. There are at present 53 Jersey females; 25 F_1 Sindhi x Jersey heifers and three bulls; 23 Sahiwal x Jersey heifers and thirteen bulls. The first six F_1 heifers calved during the year. Two of these appear likely to achieve acceptable standards of production.

(*c*) *Coat Shedding Studies.*—Histological and field studies show that both *B. taurus* and *B. indicus* cattle, and crosses between them, shed the bulk of their hair covering twice a year, in spring and autumn. *B. indicus* types shed their coats more completely in spring than *B. taurus* types which shed more completely in autumn. *B. indicus* cattle have shorter coats than *B. taurus* types at all times of the year. Examination of length and diameter of individual hairs in samples taken from the various breeds and crosses showed that the short summer coat is composed of fewer coarser hairs than the winter coat. Crossbred animals had short, coarse, summer coats similar to their *B. indicus* parents, and long winter coats shorter than their *B. taurus* parents. Although shedding rate in the spring was as low as that of their European parents it was sufficient to remove long winter hairs. They then shed heavily in autumn and grew a long winter coat.

(*d*) *Sweat Gland Studies.*—The breed survey so far indicates that seasonal differences in sweat gland volume occur in all the European dairy breeds covered by this study.

7. BEEF PRODUCTION IN AUSTRALIA.

(Division of Animal Health and Production.)

The following studies are under the direction of the William McIlrath Fellow in Animal Husbandry at the McMaster Laboratory.

(*a*) *Co-ordination of Beef Cattle Investigations.*—A report prepared for the Ninth Meeting of the Technical Sub-committee on Beef Cattle Production (Brisbane, July, 1958) reviewed most of the relevant research projects conducted by State Departments of Agriculture and C.S.I.R.O. The field covered included studies on comparative seasonal performance, upgrading from dairy stock, comparative performance on native and improved pastures, production performance recording, dentition, drought feeding, use of phosphate supplements, breed comparisons and the effect of crossbreeding, hormone implants, milk production, grazing behaviour, water consumption, herd improvement projects, supplementary feeding, performance of northern-bred steers when transferred to improved pastures in a southern environment, autumn *versus* spring calving, economics of the store cattle trade, stall- and yard-feeding, and carcass appraisal.

(*b*) *Use of Growth Hormones in Beef Production.*—As part of the co-ordination activities, results collected mainly by officers of State Departments of Agriculture were analysed. Data had been collected from over 1,000 treated and control steers in experiments undertaken in all States under a wide range of nutritional conditions and with different breeds and age groups. In all but 7 per cent. of experiments, increased growth responses, which ranged for individual groups from a mean of 2 lb. per steer to as high as 87 lb., were obtained following treatment with hexoestrol. Dressing percentages of untreated steers, however, were higher in some experiments. "Eye muscle" development of treated animals was usually increased and fat cover decreased. Undesirable side effects, similar to those recorded overseas, were noted in some experiments.

(*c*) *Nutrition of Stud Cattle.*—Collection was continued of nutritional data on two Hereford stud properties. These records are providing accurate nutritional data on the feed requirements of stud cattle of different age groups and on nutritional disorders among stud stock.

(*d*) *Carcass Appraisal Studies.*—Subjective and objective data were collected, prior to and after slaughter, from beef cattle exhibited at the annual Fat Stock and Carcass Show conducted by the Royal Agricultural Society of New South Wales.

(*e*) *Prenatal Development of Skin and Hair in Cattle* (Sheep Biology Laboratory, Prospect).—The work on foetuses and new-born calves of British breeds has now been extended to Zebu x Hereford and Zebu x Shorthorn foetuses and calves. All the foetuses have a common sire and are from cows artificially inseminated at the National Cattle Breeding Station, Rockhampton. Initiation and development of follicles and hairs show no marked differences from those for the British breeds.

(*f*) *Drought Feeding of Cattle* (Regional Pastoral Laboratory, Armidale). (i) *Whole and Crushed Wheat.*—Herefords in poor condition (mean weight 450 lb.) were fed a daily ration of 3.5 lb. wheat either whole or crushed. Over an eight-week period cattle on whole wheat lost 38 lb. liveweight and those on crushed wheat, 21 lb. The non-significant difference in liveweight was associated with a significant ($P > 0.001$) increase in digestibility of the crushed wheat. Advantages of crushing wheat may be offset by cost of processing, increased risk of mechanical losses during feeding, and a greater likelihood of digestive disturbances.

(ii) *Daily and Weekly Feeding and Subsequent Weight Gains.*—Over nineteen weeks on all grain rations cattle fed daily lost slightly less weight (58 lb.) than those fed weekly (66 lb.), but the difference was not significant. There were no losses in the daily fed group but two died out of ten in the group fed weekly. For the first three months after being placed on sown pastures all animals in both groups gained more than 3 lb. per head per day.

(*g*) *Adaptation to a Tropical Environment* (Rockhampton Laboratory. (i) *Coat Type and Performance.*—To elucidate the relationship between coat type and growth rate coats of 40 calves were kept clipped for twelve months and performance compared with that of a similar group left unclipped. Although body temperatures in the clipped group were significantly lowered, growth rates were not enhanced. Coat type and growth rate appear related by virtue of a common metabolic cause, but the significance of heat tolerance is not supported as a link between coat type and growth rate.

(ii) *Analysis of Coat Characters.*—In subjective assessments, coat type is determined by depth, " body ", and " handle ". In objective terms, depth of coat and diameter of hairs have the greatest independent values in correlations with growth rate. Study of processes by which different coat types are developed and maintained is being made by measuring growth phases of hair over a period of twelve months. Rate of turnover of hairs appears important in determining the type of coat formed.

(iii) *Sweat Glands.*—Data on sweat glands and sweating rates have been extended but give little evidence of relationship between the two. Clipping had no effect on sweating rate.

(iv) *Eye Lesions.*—A paper covering the observations on the incidence of precancerous lesions of the eye in Hereford cattle in relation to lid pigmentation has been submitted for publication.

(v) *Serum B Globulins of Cattle.*—Study commenced of the Serum B globulins in relation to the ecological tolerance of pure breeds and crossbreds at " Belmont ".

8. Cattle Breeding.

(Division of Animal Health and Production.)

The following investigations are in progress at the National Cattle Breeding Station, " Belmont ", Rockhampton, Queensland. In 1958 calving was the fifth in the current series of breeding experiments.

(*a*) *Crossbreeding Project: Rates of Growth.*—Current observations confirm that Afrikander or Zebu bulls mated with Hereford or Shorthorn females give progeny which grow faster to heavier weights than Hereford and Shorthorn or Shorthorn x Hereford crossbreds. Breed differences have been recorded mainly in rate of post-weaning gain. In 1958, for the 1957 drop of these breed groups, the difference in liveweight gain to 200 days' post-weaning was 95 lb. in favour of progeny sired by bulls of exotic breeds.

The second F_1 mating was made in 1959 between crossbreds of breeding Afrikander x Hereford, Afrikander x Shorthorn, Zebu x Hereford, and Zebu x Shorthorn; 242 females were included in this mating.

(*b*) *Conformation-Carcass Studies.*—These studies were commenced in 1958 when 32 steers of the 1954 drop were killed in groups of eight at the same age so that all breeds were represented in each kill. Conformation and carcass studies on this material were seriously affected by differences in liveweight between breeds, the Brahman crossbreds being heavier. Major breed difference was in dressing out percentage which is most readily accounted for by differences in liveweight and in girth measurement. Taking all the animals as a single population and removing variation due to liveweight, differences were recorded in length of carcass, depth of loin, and thickness of carcass behind the shoulder, the latter two characters being negatively correlated. Only thickness of carcass behind the shoulder gave any indication of dressing out percentage. Associated studies were made on cannon bone weights, hides, and diameter of muscle fibres.

From experience gained with this group it was decided that material for subsequent studies should be obtained from steers killed at approximately 1,000 lb. liveweight. To date 70 of the 1955 drop steers have been killed but collection and examination of data have been delayed because all breeds have not yet reached the prescribed killing weight.

(*c*) *Copper Supplementation of Beef Cattle.*—In 1957-58 the supplementation of yearling Hereford cattle with 400 mg. of copper gylcinate parenterally at three-monthly intervals for a year produced no significant increase in liveweight gain, although liver copper status of the treated group was raised considerably. The effect is now being studied of copper supplementation of breeding cows on the birthweight and liveweight gain of their calves.

9. Sweat Glands in Cattle.

(Animal Genetics Section.)

The shape of sweat glands in cattle is very constant from season to season despite a 30 per cent. drop in volume during the summer. This measurement has therefore been used to compare breeds. Different breeds are characterized by glands of particular shapes. The Zebu has a sack-like gland, the Shorthorn a coiled gland. Jerseys have glands resembling Zebus in shape, Ayrshires and Guernseys mostly resemble Shorthorns, but a few individuals resemble Zebus. The inheritance of shape is being studied in crosses between Shorthorns and Zebus. Research elsewhere suggest that skin activity of cattle is more an index of the nature of an animal than a direct cause of its ability to withstand tropical conditions. Studies of mouse skin are therefore of particular interest. It has already been shown that oestrogens affect the hair cycles of mice as does lactation. Different genotypes have also different hair cycles, and there is a maternal effect on hair cycles. This work will be continued as part of the investigation into the basic systemic animal characteristics affecting skin and hair growth.

IX. ENTOMOLOGY.

1. General.

All forms of agricultural production, both plant and animal, are subject to the depredations of thousands of species of insects, mites, and ticks which cause serious harm and loss throughout the rural industries. To prevent or reduce this damage the Division of Entomology investigates the various insect pests. Research on insects affecting animals is done partly in co-operation with the Division of Animal Health and Production and is reported in Chapters VII. and VIII. The Division co-operates with the Division of Forest Products in the study of pests of timber (see Section 14 of this Chapter, and Chapter XIV., Section 6), with the Division of Plant Industry on certain pasture problems (see Section 3 of this Chapter), and with the Chemical Research Laboratories (see Section 16 of this Chapter).

Division of Entomology.—A Committee of the Advisory Council reviewed the research programmes of the Division in March, 1959. The emphasis of the Division's work remains on insect ecology, particularly on detailed population studies of several species. Information is lacking on the systematics, abundance, and relative importance of insects in pastures and forests.

The Division's studies on insect tissue culture now show promise of playing a part in virus investigations and in research on insecticide resistance. The United States Public Health Service has given the Division a grant to purchase equipment and employ an experimental officer for this work.

A grant of 25,000 dollars by the Rockefeller Foundation will make possible the purchase of much needed equipment which will be invaluable in the Division's work on insect biochemistry and physiology.

The Wheat Industry Research Council has provided a grant to the Division for the construction of an experimental air-tight silo.

The new field station at Ingham has been prepared for pasture spelling experiments against cattle tick, and the first experiments have now begun. Development of this station has been made possible by grants from the Australian Meat Board and the United Graziers' Association.

The Division has been engaged in co-operative work with the New South Wales Department of Agriculture on the Argentine ant and the Australian plague locust, and on other investigations with the Australian National University, the University of Melbourne, the Forestry Commission of New South Wales, the Western Australian Forests Department, the University of Sydney, the Queensland Department of Agriculture and Stock, the Queensland Department of Public Lands, and the Victorian Department of Lands and Survey. Special acknowledgment is made of assistance given by the University of Hawaii and the United States Department of Agriculture in the fruit fly project.

2. Insect Physiology and Toxicology.

(Division of Entomology.)

(*a*) *Digestion of Wool by Insects.*—Following studies on the proteases of the wool-digesting insects, the mechanism of reduction of the disulphide bonds of wool has been investigated in the gut of these insects. The clothes moth larva possesses a number of reductases of disulphide bonds, probably the most important of which is cystine reductase. The effect of thiols on digestion of wool by these insects is considerable, and reductases may play an important part in this process. The dehydrogenases, which are essential in this mechanism, are also being studied.

(*b*) *Glycoproteins of the Cuticle.*—Some of the protein in arthropod cuticles is bound to chitin by covalent bonds forming a glycoprotein. In the larval cuticle of a beetle about 56 per cent. of the proteins are so bound, giving a glycoprotein composed of approximately equal amounts of chitin and protein. On the other hand, in the cuticle of a crab the glycoprotein only contains about 5 per cent. protein.

Fractional precipitation of cuticular glycoproteins by acetone from aqueous lithium thiocyanate has shown the glycoprotein to be polydisperse. Acidic hydrolysis of a number of samples of chitin, prepared by alkaline digestion, indicates that the protein is linked to the chitin through aspartyl or histidyl residues or both.

(*c*) *Hardening of the Cuticle.*—A study has commenced of methods of isolation from hardened cuticles of compounds to provide direct evidence on reactions which have occurred during the formation of the hard cuticle. Hard cuticles and heavily tanned proteins appear resistant to the action of proteolytic enzymes. However, much of the protein of larval cuticles can be removed.

(*d*) *Chitinase.*—The digestive and cuticular chitinases of insects are being examined as part of an investigation on the production and breakdown of chitin. The presence of chitanase has been confirmed on the freshly cast skin of the cockroach and an active chitinase has been detected in the digestive juices of a small proportion of the species so far tested.

(*e*) *Fine Structure of Insect Digestive Tract.*—Electron microscopy of sections of the midgut of the sheep blowfly larva has revealed an extremely diverse fine structure of the many different cell types which occur. In addition to its digestive function, the midgut is the site of many important metabolic activities.

(*f*) *Blowfly Oviposition Behaviour.*—The odour of a liquid medium containing powdered milk and yeast stimulated *Phormia regina* to oviposit. In the presence of a sufficient odour, contact stimulation by the same medium does not increase egg laying. The main receptors of the odour are located on the antennae and palps. Evidence was also obtained for olfactory reception by the ovipositor.

Vapours given off by a mixture of indole and ammonium carbonate elicit oviposition by *Lucilia cuprina* in the absence of any contact stimulus. Indole vapour alone and carbon dioxide alone stimulate female flies to oviposit, but ammonia alone has little or no effect.

(*g*) *Food and Blowfly Activity.*—Phormia fed on glucose, fucose, or mannose are less active than flies starved for 24 hours after feeding on 0.1 M sucrose. Metabolic state and blood sugar concentration are not determinants of activity; nor is the mechanism identical with that by which feeding and starvation control taste threshold. Locomotor activity is a function of crop volume and hence, perhaps, of the rate of crop emptying.

(*h*) *Flight Muscle Sarcosomes.*—The relatively large interfibrillar mitochondria or sarcosomes found in the flight muscles of some insect orders contain the enzymes involved in the metabolism providing the energy for flight. Their size and ease of preparation without strong mechanical stress render them particularly suitable for general studies on subcellular organelles. The composition and structure of the membrane systems in sarcosomes are being studied to interpret their biochemical and physiological behaviour. A method has been established for isolating sarcosomes and, in turn, sarcosome membranes from the flight muscle of the sheep blowfly, *Lucilia cuprina.*

3. Insects and Viruses.

(Division of Entomology.)

(*a*) *Viruses of Plants.* (i) *Subterranean Clover Stunt.*—Following the demonstration that the variety Tallarook is resistant to the virus disease subterranean clover stunt, a programme was undertaken in co-operation with the Division of Plant Industry to test for resistance in subterranean clover hybrids. A number of strains more resistant than Tallarook have already been detected, and some of these have desirable agronomic characteristics. The disease may eventually be controlled by the use of resistant varieties.

(ii) *Maize Wallaby Ear Disease.*—This is caused by the feeding of the leafhopper, *Cicadulina bimaculata.* To obtain a colony of leafhoppers which did not cause the disease, approximately 80 collections were made between Taree, New South Wales, and Kingaroy, Queensland. These were brought to Canberra where the progeny of every colony eventually caused the symptoms of the disease. Crown or root grafting of maize and heat treatment of the leafhoppers are being tried to determine whether the disease is due to a virus or a salivary toxin.

(iii) *Other Viruses.*—An attempt is being made to purify cauliflower mosaic virus. This is a particularly interesting virus, having some characteristics of both persistent and non-persistent types of aphid-transmitted viruses.

Progress has also been made, in collaboration with the Department of Microbiology of the Australian National University, in developing an antiserum for the study of potato leaf roll virus.

(*b*) *Insect Tissue Culture.*—Progress has been made in the development of techniques for insect tissue culture. In addition to tissues of Lepidoptera previously studied, cells from the cockroach and the mosquito have been kept alive for considerable periods. It is hoped before long to grow viruses in these tissue cultures. The effect is also being investigated of insecticides on insect tissues in culture.

4. POPULATION DYNAMICS.

(Division of Entomology.)

(*a*) *Theoretical and Laboratory Studies.*—Investigations have continued on laboratory populations of the Australian sheep blowfly, *Lucilia cuprina*. New strains of this blowfly have been studied together with the influence exercised by population dynamics during the natural selection of these strains. Even when very great changes in the properties of the insects were so selected, the ratio of offspring to parents, averaged over any period of moderate length, never departed from unity by more than a small fraction. The disturbing influence of rapidly changing properties is automatically compensated by density-governing reaction which maintains the population in a state of stability throughout the period of selection. This is closely analagous to the already demonstrated ability of density-governing reaction to hold populations in a state of stability in environments having widely differing degrees of favorability, or in which conditions fluctuate in favorability very greatly with time.

(*b*) *Field Studies.* (i) *Psyllid Investigations.*—Work on *Cardiaspina,* major outbreaks of which are still in progress, has consisted mainly of studies designed to evaluate the parts played by natural enemies, particularly encyrtid parasites, in the numerical limitation of the psyllid in those areas in which outbreaks have not occurred. Under conditions favorable to parasite attack, two species of encyrtid can oppose psyllid increase by destroying higher percentages of individuals when psyllid numbers are relatively high than when they are low. It has still to be determined if this opposition to population growth is sufficiently strong and frequent to hold psyllid numbers at low average levels of population density. In one of the four areas used in the study, parasite attack may have already halted a recent population increase.

(ii) *Eucalypt-defoliating Insects.*—Two eucalypt-defoliating insects are being investigated, the saw-fly, *Perga affinis,* and the chrysomelid, *Paropsis reticulata,* to discover the mechanisms underlying the density regulation of insect populations under field conditions.

In early 1958 the sawfly was extremely abundant in many areas, and, because of the interest attaching to the study of a population during the period of decline that follows an outbreak, particular attention has been devoted to this species. Observations have been made for one and a half generations in over 150 study sites on the nature and incidence of the factors that influence natality and mortality in populations of the saw-fly.

(iii) *The Gum Leaf Skeletonizer* (*Roeselia* sp.).—The outbreak of the defoliating moth, *Roeselia,* which has caused extensive and severe damage to the valuable red gum forests along the Murray River, ceased while a co-operative study with the New South Wales Forestry Commission was still in the preliminary stages. The principal factors responsible for the spectacular population crash were diseases. At least two pathogenic fungi were involved and possibly also a virus.

5. INSECT SYSTEMATICS.

(Division of Entomology.)

Studies on the classification and identification of Australian insects are essential in many fields of pure and applied entomology. The need for such studies is being increasingly felt, not only in relation to the Division's research programme, but by other institutions, which are turning more and more to the Organization for assistance in insect systematics. A major research tool in this field is the comprehensive collection of Australian insects housed in the Division. Over the years, this has acquired the status of a great national scientific asset. A senior member of the Division's staff has now been designated curator of the collection, with the responsibility of ensuring its proper maintenance, fostering its further growth, and promoting its more extensive use.

The following are the main lines of work being pursued:—

(*a*) *Diptera.*—Work is nearing completion on the Calliphoridae (blowflies), which contains many species of importance.

(*b*) *Hymenoptera.*—Many manuscripts have been completed on the systematics of the Hymenoptera, particularly the Chalcidoidea, and await only illustrations for publication.

(*c*) *Lepidoptera.*—A revision of the Australian rice stem borers (Schoenobiinae, Pyralidae) is nearing completion. The species which has consistently caused the most damage to experimental rice plantings in northern Australia has proved to be the white rice stem borer of Java, known in the literature as *Scirpophaga innotata.* One other species of the group may cause damage at times.

Progress has been made with a comprehensive revision of the Australian Tortricidae.

(*d*) *Scarabaeoidea.*—The Divisional collection of Melolonthinae (cockchafers) has been re-arranged according to a partial revision of that sub-family by E. B. Britton, of the British Museum.

(*e*) *Acridoidea.*—Dr. J. A. G. Rehn of the United States of America is continuing work on Volume IV. of his monograph of Australian Acridoidea. A study has been made of type specimens in European museums, as a result of which much clarification of nomenclature may be expected. A comprehensive cytotaxonomic revision of a peculiarly Australian group of grasshoppers, the Morabinae, has revealed more than 150 species of which three-quarters are undescribed.

(*f*) *Psyllidae.*—A revision of the genus *Cardiaspina* is now almost ready for publication, and some work has been done on other genera.

6. ECOLOGY OF ORCHARD PESTS.

(Division of Entomology.)

(*a*) *Queensland Fruit Fly* (In co-operation with Department of Zoology, University of Sydney).—Experiments on dispersal of adults in orchards and in areas of dry bushland have indicated that rate of dispersal in this species is quite low. There is probably a high mortality in flies released in dry bushland. Immature adults appear to disperse from orchards more rapidly than mature adults.

The availability of food for adults in orchards has been studied. Protein appeared to be plentiful in an orchard where fruit was present, but scarce in an orchard where there was no fruit. Various sources of carbohydrate for flies in the field have been tested in the laboratory, but the main source of protein has not yet been identified.

Useful information has been obtained on the nutritional requirements of adults. A mixture of pure amino acids and inorganic salts has been found which permits maturation of ovaries and the production of fertile eggs.

(*b*) *Codling Moth.*—This study began in 1957 with a preliminary survey of the situation in most fruit-growing centres of New South Wales. It was extended in 1958-59 by detailed investigations near Canberra of some aspects of the pests's bionomics, behaviour, and relative injuriousness.

A spray programme was initiated incorporating selective materials only and the results are encouraging. Besides allowing satisfactory control of codling moth and fungus diseases, the selective sprays did not hinder the elimination by predators, in the first half of the growing season, of an endemic infestation of phytophagous mites. Occurrence of other insect pests remained negligible throughout in the experimental plots.

Interesting differences were noted in the relative amount of injury caused by the codling moth to comparable trees of different apple varieties. The constancy, nature, and causes of these differences are being investigated in conjunction with other aspects of the pest's ecology.

7. LOCUSTS AND GRASSHOPPERS.

(Division of Entomology.)

(*a*) *The Australian Plague Locust.*—Preparations for the Commonwealth-State trial of the strategy of outbreak suppression were continued during the second half of 1958. The soil survey needed as a guide for the location of early swarms in the Bogan-Macquarie outbreak area is now about two-thirds complete. An assessment of the locust density over the outbreak area as a whole in November 1958, gave a value about four times greater than any previous one since the system of routine assessments was initiated; a few flying swarms were also observed. In the following generation a major outbreak commenced. The Committee of Management for the trial campaign decided, against the advice of the Organization's representative, not to undertake the trial. The future of the trial project is now uncertain.

(*b*) *Solitary Grasshoppers.*—A long-term study of numerical regulation in *Phaulacridium vittatum* was completed by further intensive observations.

Sufficient data are now available on the importance of pasture structure in numerical regulation of grasshopper populations to relate the levels of infestation of a number of species including *P. vittatum, Austroicetes pusilla, Peakesia fuscomaculatus,* and *Oedaleus australis* to pasture classification based on structure as affected by grazing intensity and species composition. High levels of grasshopper infestation are a direct result of overstocking, inadequate maintenance of improved pastures, or clearing of unsuitable areas for pasture, e.g. dry sclerophyll forest formations.

Heavy infestations of potential pest species in improved pastures in the Southern Tablelands can be reduced to insignificant levels by excluding stock for one to two grasshopper generations. Exclusion is warranted only in instances of persistently heavy infestations or in areas of mixed cultivation and grazing in which grasshopper populations constitute a potential threat to crops.

8. PASTURE CATERPILLARS.

(Division of Entomology.)

Environmental factors have been studied which influence the annual migrations and aestivation of the cutworm *Agrotis infusa,* which is one of a series of cutworms and armyworms which injure native and sown pastures and field crops in eastern Australia. The populations of aestivating moths at Mount Gingera, Australian Capital Territory, during the summer were low, following a winter when little economic damage was caused.

Temperature and photoperiod, two factors which may induce insect diapause, are being studied to determine if they affect the incidence of reproductive diapause in *A. infusa.* Experiments are in progress employing temperature régimes comparable with those operating in the field during winter outbreaks.

9. LUCERNE FLEA AND RED-LEGGED EARTH MITE.

(Division of Entomology.)

(*a*) *Insecticidal Control.*—Experiments on the use of systemic insecticides have been extremely promising. In pot trials, seed treatment with carbon preparations of three of these insecticides has produced subterranean clover seedlings which remain toxic to both lucerne flea and red-legged earth mite for periods up to two and a half months after emergence.

One small-scale field trial has produced seedlings of subterranean clover, common vetch, and field pea toxic to the red-legged earth mite.

(*b*) *Lucerne Flea Ecology.*—Experiments with pasture and soil samples collected in the field and infested with *S. viridis* in the laboratory have shown that, where high densities of the flea had occurred, the environment had become contaminated, thus increasing the mortality of both the existing inhabitants and new inhabitants to the area. This contamination was demonstrated not only in field samples but also in laboratory cages where the environment was " conditioned " by different densities of the flea. The principal site of the contamination was the surface of the soil.

Physiological changes in the fleas at high densities include a marked increase in the quantity of granular stored material in the fat-body. The quantity of this material was also greater in fleas collected towards the end of the season than in those collected early in the season.

10. CATTLE TICK.

(Division of Entomology.)

This work is reported in Chapter VIII., Section 5.

11. SHEEP BLOWFLIES.

(Division of Entomology.)

This work is reported in Chapter VII., Section 20.

12. INSECT PESTS OF STORED PRODUCTS.

(Division of Entomology.)

Investigations have continued on the effects of oxygen depletion on insect pests of stored grain, and on the trends of insect population density under conditions of controlled oxygen leakage. An officer is overseas at the Pest Infestation Laboratory at Slough in the United Kingdom investigating the latest trends in the protection of grain and other stored products in North and South America. Financial support for part of this visit was given by the Department of Primary Industry.

Plans for an experimental air-tight silo have been obtained from Argentina and a site has been selected near Harden-Murrumburrah in New South Wales. This work is being supported by a special grant from the Wheat Industry Research Council. The silo will make it possible to test this method of grain storage commercially, and provide a means of studying air-tight storage on a large scale.

13. BIOLOGICAL CONTROL.

(Division of Entomology.)

(*a*) *Weed Problems.* (i) *St. John's Wort* (Hypericum perforatum).—No further distribution of St. John's wort insects has been undertaken. The seed fly *Zeuxidiplosis giardi* is now well established in several districts.

(ii) *Ragwort.*—Further attempts to establish *Tyria jacobaeae* in Gippsland are not justified. In January 1959, a polyhedrosis disease unexpectedly wiped out nearly the total field population of 100,000 larvae.

Several hundred adults of the seed fly *Pegohylemyia jacobaeae* were released in Gippsland, and a further consignment of pupae imported from New Zealand.

(iii) *Noogoora Burr* (Xanthium pungens).—Work has continued in quarantine on the biology of the imported cerambycid beetles *Mecas saturnina* and *Nupserha antennata* to assess the advisability of subsequently releasing these insects in Australia for the control of Noogoora burr.

M. saturnina has proved a hardy species, able to tolerate a range of conditions of temperature and humidity. Climatic conditions over wide areas of Australia should be suitable for its establishment. Major damage to burr plants is caused both by the adult and larva. The adult activity kills the growing apex of the stem, temporarily checking the growth of the plant, while the larval damage renders the plant likely to be broken off at ground level. This can occur before the plant has set seed.

N. antennata is less resistant to cold conditions than *M. saturnina* and successful establishment may be possible only in the warmer areas of Australia. Adult damage to burr plants is negligible, but the young larva tends to check the growth of the plant temporarily.

(*b*) *Insect Problems.* (i) *Cabbage White Butterfly* (Pieris rapae).—Field tests have been completed with a granulosis virus disease of cabbage white butterfly. This virus, discovered recently in Australia, proved quite effective in field use. An epizootic induced by spraying virus granules persists for the duration of a crop.

(ii) *Cabbage Moth* (Plutella maculipennis).—*Bacillus thuringiensis* has been imported into Australia and it is intended to experiment with this bacillus in quarantine as a means of controlling cabbage moth.

(iii) *Green Vegetable Bug* (Nezara viridula).—Liberation of the Italian strain of *Microphanurus basalis* terminated, 113,000 adults having been liberated.

Bogosia antinorii was imported from Kenya and liberated in small numbers in the Australian Capital Territory.

Studies were continued of the reproduction of *Ooencyrtus submetallicus.*

(iv) *Brown Vegetable Weevil* (Listroderes obliquus).—Three larval parasites (*Tersilochus* spp.) of this weevil, imported from South America, are being cultured at Canberra, and liberations of all species have been made in the Australian Capital Territory and New South Wales.

(v) *Queensland Fruit Fly* (Strumeta tryoni).—The programme initiated in mid March 1958 of releasing fruit-fly parasites shipped in from the C.S.I.R.O. field station in Hawaii is continuing. So far, 448,000 wasps belonging to four species of *Opius* have been released, 59,000 in Western Australia against Mediterranean fruit fly and the balance between Cairns, Queensland, and Sydney, against Queensland fruit fly.

The most important parasite, *Opius oophilus,* may be established in some areas.

(vi) *Wax Scales* (*Ceroplastes* spp.).—Comparative studies have been started of the climatic pattern of the distribution of *Ceroplastes destructor* in Australia and South Africa.

(vii) *Nematode Parasites of Curl Grubs.*—One or more species of insect parasitic nematodes (*Neoaplectana* spp.) will be introduced to test their value as parasites of the black beetle and other curl grubs. A recent grant by the Dairy Research Grants Committee has enabled orders to be placed for the necessary equipment.

(viii) Diomus pumilio.—At the request of the Canadian Department of Agriculture, four consignments of this predator, totalling 14,700 insects, were sent to Canada for the control of the balsam woolly aphid.

14. TERMITES AND OTHER WOOD-DESTROYING INSECTS.

(Division of Entomology.)

(*a*) *Termite Investigations.* (i) *Laboratory Studies.*—In co-operation with the Western Australian Forests Department, a survey is in progress of the natural durability to termite attack of several Western Australian commercial timbers.

Tests to determine the efficiency of dip-diffusion treatments of *Pinus radiata* timber against *Coptotermes* attack have been completed. This project, in co-operation with the Division of Forest Products, has shown that under the experimental conditions the best dip-diffusion treatments —sodium arsenite or fluoroborate-chromium-arsenic mixture—are at least as effective as the best available pressure treatments.

Also in co-operation with the Division of Forest Products the effectiveness is being studied of varying additions of chlordane or white arsenic to the glue line of karri plywood to prevent termite attack. All levels of both compounds so far tested have proved completely effective, and the threshold values necessary for protection are being established.

Laboratory tests have been made of various plastic, gypsum plaster boards and insecticide-treated hardboards. With the latter product the high efficiency has been demonstrated of small additions of either aldrin or dieldrin.

Both dense and "no-fines" concrete can be made termite proof by the addition of a small amount of dieldrin, and this treatment is highly resistant to both leaching and volatilization influences.

(ii) *Field Studies.*—Surface treatments have shown that 5 per cent. pentachlorphenol is the only treatment still effective against *Nasutitermes exitiosus* after three years.

Soil treatment tests have continued and all materials mentioned in last year's Annual Report remain effective.

Field testing with *Mastotermes* was resumed and at three test sites at Rollingstone, Queensland, samples of more than 30 types of plastic-covered, lead-sheathed, or bitumen-served cables have been exposed to the attack of this termite.

(iii) *Termites in Forest Trees.*—A technique for obtaining termites from colonies in living trees was developed and 775,000 termites were obtained from one colony.

Territory studies were made of three mound-building species of *Coptotermes* in Western Australia. In the mallee country north of the Murchison River *C. brunneus* was found attacking living eucalypts, the galleries extending over 90 feet from the mound.

Near Pingrup, Western Australia, a colony of *C. acinaciformis* was traced from the mound to several gimlet gums (*Eucalyptus salubris*). The area explored by this colony was similar to that found in previous studies of colonies occurring in living trees in New South Wales.

In the same locality, a mound colony of *C. frenchi* did not attack living trees.

(iv) Lyctus *Investigations.*—An investigation of the *Lyctus* susceptibility of bass (*Endospermum medullosum*) is being carried out with the co-operation of Commonwealth New Guinea Timbers Limited.

Tests have continued of the efficiency of various surface treatments for preventing *Lyctus* attack. After three years' indoor weathering the following materials are still completely effective: chlordane, lindane, aldrin, and dieldrin.

15. ANT INVESTIGATIONS.

(Division of Entomology.)

Officers of the Division have been responsible for the application of insecticides during the Argentine ant campaign in New South Wales during 1952-59 in co-operation with the New South Wales Department of Agriculture and local government bodies. All known infestations will have been sprayed by July, 1959, when C.S.I.R.O. will withdraw from active participation in the campaign.

A careful check survey of all previously treated areas was made in February-March 1959. Small colonies were found in six out of 10,795 properties and these six have been retreated.

16. INSECTICIDE INVESTIGATIONS.

(Division of Entomology.)

Further subdivision of a colony of houseflies heterogeneous in insecticide resistance has been carried out by selection for DDT tolerance and for rate of maturation. The immediate aim is to determine some of the genotypes comprising a housefly population and to isolate them as homogeneous strains which may then be bred without the inconvenience of continuously applied selection. Two such strains have been fixed, and these have proved useful reference types for studies on the biochemical and genetical mechanisms of resistance to insecticides (see Chapter XVII., Section 7 (g)).

X. WILDLIFE.

1. GENERAL.

Human activities throughout the world are inevitably affected in varying degrees by contact with wild animals and birds populating various environments. This is particularly so in relation to agricultural production; and in Australia problems arise with respect to both native and introduced mammals and birds. Native animals, such as marsupials and waterfowl, may be pests in some locations while calling for conservation elsewhere. The Organization's Wildlife Survey Section was established to study Australian wildlife problems, and the work of this Section is described below.

Wildlife Survey Section.—The research programme of the Section continued without major change.

Close collaboration continued with State departments, the Antarctic Division of the Department of External Affairs, and the universities.

Grateful acknowledgment is recorded of the assistance rendered by individual landholders in the Section's various field investigations.

Among the overseas scientists collaborating with the Section during the year were Professor D. S. Farner, of Washington State College, United States of America, who worked with officers in Perth on investigation of the reproductive physiology of Australian birds; and Mr. John Kelsall, of the Canadian Wildlife Service, who has been studying the caribou in the Canadian Arctic.

2. RABBIT INVESTIGATIONS.

(Wildlife Survey Section.)

(*a*) *Myxomatosis.*—Observations on the rabbit population at Colo Vale, in the coastal ranges of New South Wales, have been maintained, and the area is being mapped in preparation for intensive field studies. The third myxomatosis epidemic there, which began in January, 1958, continued at a moderate level and with patchy distribution until May, 1959; by that time rabbit numbers were low, although the disease had not prevented breeding. Experiments are being made to determine resistance to myxomatosis, using 60 kittens taken in the field or bred from parents captured in October, 1958.

Field investigations of virus performance, conducted at Lake Urana on behalf of the Australian National University, were concluded. Virus samples were harvested during the eighth annual epizootic in December, 1958, and January, 1959. A further fall (to 25 per cent. under laboratory testing conditions) in the mortality rate of kittens born to survivors of the previous epizootic was recorded.

In southern New South Wales and north-eastern Victoria an outbreak of myxomatosis—the most widespread and effective for some years—occurred during the summer, and virus material was collected. On the New England Tableland the first major outbreak since 1954-55 occurred after favorable rains and reduced the rabbit population considerably, indicating that the absence of major epizootics there had given little opportunity for selection for increased resistance in the rabbit population.

A fourth consignment of rabbit fleas (*Spilopsyllus cuniculi*) was received from England on 15th March, 1958, but attempts to breed them on wild rabbits under quarantine conditions again failed. The adult fleas infested the rabbits, but gonad development in the females was suppressed, for reasons not determined. In view of this, and on re-consideration of their potential value as myxomatosis vectors in Australia, experiments with rabbit fleas were abandoned.

(*b*) *Rabbit Biology and Behaviour.*—Studies of populations of wild rabbits in experimental enclosures at Gungahlin (near Canberra) and at Albury, New South Wales, were continued.

During the summer there was little reproductive activity, but as the autumn breeding season approached the rabbits formed separate groups, each with its own territory and social hierarchy. Only the dominant does, which preempted the burrows, littered in April, May, and June, and their kittens born in those months showed the highest survival rate. Subordinate does littered from July onwards, using isolated breeding stops. Intra-uterine mortality, noted in subordinate does, was highest in July. Kitten mortality increased as the season advanced and reached 95 per cent. for kittens born in November, the last month of breeding, so that the late breeding of subordinate does was of little value.

Pasture deterioration—leading to shortage of food, cessation of suckling by mothers, and premature leaving of nests by kittens—was the most important factor in kitten mortality. Drowning after heavy rains and seasonal bird predation also played a part.

The progeny of dominant does grew faster and became bigger. They were more resistant to coccidial infections. When a spontaneous outbreak of myxomatosis in the Canberra enclosure in January, 1959, reduced the population by 88 per cent., more than three-quarters of the survivors were descendants of the original dominant doe.

(*c*) *Physiology and Parasitology.*—Preliminary studies were undertaken at Canberra on water metabolism in the rabbit, to investigate the rabbit's ability to adapt to dry-country conditions. It was found that the rabbit's ability to concentrate its urine with respect to urea is little better than that of man.

Studies of digestion by rabbits indicate that production of lactic acid in the stomach depends on coprophagy and the consequent presence of faecal pellets.

In studies of the biochemistry of rabbit muscle, the effect of 2, 4-dinitrophenol on the nucleoside triphosphatase activity of purified myosin from rabbit muscle has been investigated and a report prepared.

(*d*) *Rabbit Control.*—At the request of the Leichhardt Rabbit Board (Queensland) a survey of the rabbit problem and of measures to cope with it was made in the district covered by that Board.

Advantage was taken of the knowledge of territorial behaviour of the confined rabbit populations at Albury to check the attraction offered by bait stations to established breeding populations. Territorial behaviour by the rabbits nearest to the station prevented access by others, which emphasizes the importance of bringing bait to the separate rabbit groups during the breeding season.

Bait preference tests were conducted during each of the four seasons at Canberra (25-in. rainfall) and Hay, New South Wales (12-in. rainfall). Carrots are preferred in summer and oats in winter. The advantage was confirmed of preliminary free-feeding at three-day intervals, rather than on successive days (particularly when oats are used as bait).

The influence of weathering on carrots and oats treated with "1080" was investigated. A single fall of about 1 inch of rain made carrots non-toxic, but oats retained about half of the initial potency after three such falls over a period of nine weeks. Practically all of the residual toxicity was in the husks of the oats, and none was detected in the grain. Where rain may be expected, therefore, carrot is the bait of choice if it is desired to restock pastures quickly.

Experiments are being made to check the efficiency of poisoning with oats as bait at different seasons by comparing counts of rabbits made before and after such poisoning.

Research is continuing into poisons having some degree of specificity to rabbits. Sheep are relatively insensitive to dinitro-orthocresol (" Dinoc "), but its effect on rabbits is not known. Tests of mixtures of " Dinoc " and " 1080 " are being made in the hope that the low pH of rabbit stomachs will permit unionized " Dinoc " to exert its toxic action. Preliminary results are quite encouraging, indicating that the toxic effects of the mixtures are synergistic and not merely additive.

3. KANGAROO INVESTIGATIONS.

(Wildlife Survey Section.)

Studies of euros or hill kangaroos (*Macropus robustus*) have been continued in north-western Australia, to determine the nature and extent of euro competition with sheep and the need for and possibility of euro control.

Observations made in the Abydos-Woodstock area indicate that the euro is a sedentary species. In November, 1958, marked animals were still occupying the same sites as in 1957. Although euros may move 2 or 3 miles to one or more watering places they return to their home ranges.

A number of euros were trapped in the Abydos-Woodstock area and marked for the first time or, if previously marked, examined for growth and changes in tooth patterns. In the Mount Edgar area 200 female euros were shot in November, 1958, and examined for reproductive condition. It was found that the survival rate of pouch young since February and April had been high; this coincided with winter rain. A further sample of 200 was shot in February, 1959, and the results are still being analysed.

An experimental flight was made in November, 1958, to test the possibility of aerial counting of plains kangaroos and of detecting from the air dye marks made by automatic markers. The test was highly successful.

4. DINGO INVESTIGATIONS.

(Wildlife Survey Section.)

A survey of the dingo (*Canis familiaris dingo*) problem, commenced in 1957-58, was continued in a region in north-eastern New South Wales covered by three of the four Dingo Destruction Boards in the State. Investigations were at first concentrated in sheep-raising areas, but have recently been extended to the cattle-raising areas, which contribute 60 per cent. of the scalps submitted for bounty payments each year.

Subjects covered by the study include efforts by Dingo Destruction Boards, local organizations, and individual landholders to reduce the dingo population. Current control techniques, including poisoning by aerial baiting, are being investigated. A particular study has been made of the operation of the scalp bounty system.

5. FOX INVESTIGATIONS.

(Wildlife Survey Section.)

Study has continued of the biology of the fox (*Vulpes vulpes*) in the Southern Tablelands area. Regular monthly samples are collected by shooting, and stomach contents are analysed and reproductive organs examined. A good collection of helminths of the alimentary tract is awaiting detailed examination.

Sheep (evidently mostly carrion) and rabbit are by far the most important food items by volume. In summer and autumn invertebrates, chiefly arthropods, of great taxonomic diversity, form up to 30-40 per cent. of the total food volume. Birds (including domestic varieties) are of negligible importance.

Females come into oestrus from mid-June to mid-August, coincident with maximum testicular development in males. Pups are born from mid-August to mid-October. Mean litter size, as determined by counts of corpora lutea, placental scars, embryos in uteri, and litters found, is about 4.5.

6. OTHER MAMMAL INVESTIGATIONS.

(Wildlife Survey Section.)

Australian Newsprint Mills have asked for assistance in the Florentine and Styx River areas in Tasmania, where natural regeneration of forests of *Eucalyptus* sp. (particularly *E. regnans*) is being retarded by browsing of native mammals. The animals involved are scrub wallaby (*Thylogale billardierii*), Bennett's wallaby (*Protemnodon rufogrisea*), and possum (*Trichosurus vulpecula*), and possibly a rodent in one or two localities.

Investigation on ecology and control began in November, 1958. Standardized dung counts were made in different locations, and animals were snared for marking and release to study their movements. Bennett's wallaby is primarily an open-country animal, and the possum and scrub wallaby invade burnt coupes when the first seedlings appear. Data are accumulating on the life history and general biology of all three animals.

Baiting tests show that possums can be poisoned at bait stations and that their preferred bait is apple; carrots and oats are ignored in the presence of apple.

Analysis of data collected on the marsupial anteater or numbat (*Myrmecobius fasciatus*) in Western Australia has been completed and a report prepared embodying suggestions for the conservation of this interesting species.

A detailed assessment has been made of the population study of branded seals on Macquarie Island (commenced in 1950).

7. MAGPIE GOOSE INVESTIGATIONS.

(Wildlife Survey Section.)

The main study of the magpie goose (*Anseranas semipalmata*) and its relation to rice-growing in the Northern Territory has been completed. Mass destruction would be technically difficult and of limited value in practice, and the development of any effective scaring method is improbable. It is possible, however, to prevent breeding and to disperse flocks by altering water levels in breeding swamps. Application of that procedure to seven swamps would reduce the goose problem in the Adelaide River valley to negligible proportions.

8. WILD DUCK INVESTIGATIONS.

(Wildlife Survey Section.)

The main emphasis in wild duck studies has been on the movements of several species. Since the exodus to the coast during the 1957 drought wild ducks, especially grey teal (*Anas gibberifrons*), have not been common in eastern Australia. Extensive ground and air surveys and banding have revealed heavy mortality in 1957 and early 1958, from which the wild duck populations may take years to recover.

9. MUTTON-BIRD INVESTIGATIONS.

(Wildlife Survey Section.)

Joint investigations with the Tasmanian Fauna Board into the economic biology of mutton birds (*Puffinus tenuirostris*) were continued in the Furneaux Group of islands in Bass Strait. During the season 2104 of the birds were banded, bring the total for the species to 25,543. Three banded birds were recovered in the North Pacific.

A new nesting colony has been found on the Tollgates Islands off Bateman's Bay, this being the first breeding record for New South Wales. The birds breed there together with the non-migratory *P. pacificus*. Studies are being made of the biology of the colony.

10. MAGPIE INVESTIGATIONS.

(Wildlife Survey Section.)

Nearly 600 magpies (*Gymnorhina tibicen*) in flocks were banded in 1958-59 to study dispersal of the non-sedentary part of the population, and collection has begun of banded specimens of known age. Social organization and territory-holding by magpies extend into open country not suitable for breeding. Breeding (normally commencing at three years of age) is delayed when birds are not members of a group located in suitable breeding territory.

11. OTHER BIRD INVESTIGATIONS.

(Wildlife Survey Section.)

A study of white ibis (*Threskiornis molucca*) and straw-necked ibis (*T. spinicollis*) has been concluded.

Trapping of ravens (*Corvus coronoides*) is being studied, and an extensive field trial with 25 traps is in progress on stations in the Cowra district.

In Western Australia field studies were continued on bird breeding cycles, which began in 1953. Experiments were begun on the control of breeding cycles in arid-country birds and transequatorial migrants. The latter group comprises shore birds or waders that breed in northern Siberia and whose migratory pattern is therefore the reverse of that of the mutton birds. Work on the arid-country species has indicated that water balance is a major controlling factor in the reproductive cycles of such species as the zebra finch (*Taeniopygia castanotis*).

The first analysis has been made of 152 food samples of Macquarie Islands birds, and 204 study skins of those birds have been prepared.

12. BIRD-BANDING SCHEME.

(Wildlife Survey Section.)

During 1958-59 the number of effective banders increased from 54 to 97, and 36,938 new birds were banded, bringing the total to 103,679. The total number of species banded was increased from 182 to 253. Fewer ducks were banded than in 1957-58. but increased numbers of other species.

New developments are: (*a*) formation of regional banding groups in Perth, Adelaide, Melbourne, and Sydney; and (*b*) emphasis on co-ordinated banding of economic species, especially crows (*Corvus* spp.), birds of prey (Accipitres), and silvereyes (*Zosterops* spp.).

XI. LAND RESEARCH.

1. GENERAL.

The history of rural settlement in Australia and its Territories has been one of emphasis on the more accessible and easily developed regions, and large portions of the land have been only sparsely occupied. Low rainfall, short growing seasons, inadequate water, poor soils, and remoteness from markets have been contributory causes.

Although large tracts of country remain virtually undeveloped, the rapid growth of population and technological understanding have emphasized the importance of assessing the potential, not only of sparsely populated regions, but also of areas which are looked on as traditionally highly productive. Expanding exports, and internal demands for greater production, necessitate assessment of all regions in terms of their potential land use.

The Division of Land Research and Regional Survey is engaged in land surveys of potentialities and problems of regions which Commonwealth, State, or local organizations have a specific interest in developing. These surveys provide description of the region, assessment for improved land use, and analysis of major problems retarding development.

Until recently this work has been devoted mainly to underdeveloped areas of dry monsoon zones of the far north, arid interior, and the Territories of Papua and New Guinea. This work has now been extended to developed areas, commencing with a comprehensive land survey of the Hunter Valley in New South Wales. The Division has established research centres and specialist groups at Katherine, Kimberley, Alice Springs, the coastal plains of Northern Territory, and Canberra.

In addition to the work of the Division of Land Research and Regional Survey much research is being carried out by other Divisions of the Organization on the development of low producing areas in the less isolated regions.

The Division of Biochemistry and General Nutrition is investigating problems of plant and animal nutrition on the Coonalpyn Downs in South Australia (see Chapter VI.); the Division of Animal Health and Production is breeding cattle at " Belmont ", Rockhampton, Queensland, with the object of developing animals suited to our northern environment (see Chapter V., Section 9); the Plant and Soils Laboratory is studying the problem of increasing productivity in many parts of Queensland, including the wallum and brigalow country (see Chapter III., Section 20); and the Division of Soils is making soil surveys throughout the Commonwealth (see Chapter II.). Allied work is also carried out by the Division of Plant Industry on plant and pasture ecology (see Chapter III.).

The Agricultural Research Liaison Section is participating in the co-operative study of the Southern Tablelands to assess existing and potential agricultural resources of this region (see Chapter XXX., Section 3).

Division of Land Research and Regional Survey.—A development in the Division's activities has been the establishment near Darwin of a research station to study problems of rice production on the subcoastal plains of the Northern Territory. This followed a request from the Department of Territories.

At the invitation of U.N.E.S.C.O. and the Government of India, the Chief of the Division spent six weeks in Rajasthan advising on the establishment of an arid zone research centre. He also attended as Australian delegate the Sixth Session of the International Rice Commission in Tokyo in October.

Co-operation has been maintained with the Division of Meteorological Physics, with the Western Australian Department of Agriculture, and with the Universities of Sydney and Queensland. Collaborative work has continued with the Northern Territory Administration on range seeding in central Australia aided by a grant from the Australian Meat Board.

Acknowledgment is made of co-operation from the Bureau of Mineral Resources and the Division of Mapping of the Commonwealth Department of National Development, the Papua and New Guinea Administration, and the Western Australian Department of Mines.

2. REGIONAL SURVEYS.

(Division of Land Research and Regional Survey.)

The two regional survey units have continued operations, one on the mainland and one in the Territories of Papua and New Guinea. Since 1946 the first unit has completed surveys mostly in northern and central Australia, covering a total area of 660,000 square miles. The New Guinea unit, established in 1953 at the request of the Department of Territories, has covered 15,000 square miles.

(*a*) *Australian Mainland Survey Unit.* (i) *Wiluna-Meekatharra Area.*—Field work in this area (25,000 square miles) in central Western Australia was completed in July-September. Officers of the Geological Survey and Agriculture Department of Western Australia co-operated in this project.

The western half of the area near Meekatharra is drained by the headwaters of the Murchison River and early settlement was along these waterways with their saltbush pastures. Sheep grazing has caused severe degradation, particularly the loss of edible shrubs. The central and eastern part has been occupied for a shorter period and pastures have not suffered marked degradation.

Deeply weathered materials associated with the widespread Australian Tertiary peneplain are common throughout the area, and the dissection since that time has not been great. The outstanding characteristic of the soils is general shallowness and widespread siliceous hardpans in the lower soil horizons. Mulga and spinifex are the most common vegetation forms with banding patterns in vegetation, generally associated with slight microrelief changes. Ground-water at shallow depth is widespread and in a few places has been used for the production of irrigated fodder crops.

(ii) *Northern Territory Mission Islands.*—Two officers made a brief survey in April of the lands and agriculture on the Mission Islands to the east and north of Darwin.

At present agricultural production is not adequate for food requirements but might be made adequate by greater efficiency in production and by bringing more land into cultivation.

Coconuts are grown but their yields are very low and do not offer prospects for native agriculture.

(*b*) *Papua-New Guinea Survey Unit.*—The Lower Ramu-Atitau Area (4,700 square miles) in the Madang district of New Guinea was surveyed in August-October. A geologist from the Bureau of Mineral Resources accompanied the team.

Although the area includes the large coastal Adelbert Range with elevations up to 4,000 feet above sea-level, and the north-eastern slopes of the Schrader Range rising beyond 7,000 feet, it is generally a typical New Guinea lowland area, with hot and humid climate, marked by a distinct drier season. It has a dense cover of rain forest, which gives way to extensive grasslands only in some hilly areas near the coast. Low but severely dissected hilly land is the most extensive type of country but there are also extensive flood-plains on the Lower Ramu River and its tributaries.

In round figures the area comprises 1,000 square miles of rugged mountains, 1,800 square miles of strongly dissected steep hills, 750 square miles of regularly flooded land, 650 square miles of swamps, and only 500 square miles of flat land without or with minor restrictions on land use.

The population is largely concentrated in the mountains and hills, where there is little scope for improving agriculture beyond extensive shifting cultivation. A rough assessment of the hydrological conditions and agricultural possibilities in the flooded country was made by questioning the local population, measuring river and ground-water levels, and evaluating the significance of differences in vegetation and soils. Before the potential can be assessed much more hydrological and land level information must be collected and agronomic knowledge gained from experimental projects.

3. GEOMORPHOLOGY.

(Division of Land Research and Regional Survey.)

Much of the work of the Geomorphology Unit falls under the heading of regional survey, and consideration is here given only to additional aspects, including geomorphological studies in survey areas and work done in collaboration with other specialists.

A report is in preparation on field investigations in the Alice Springs area dealing with evolution of land surfaces, past climates, and history of drainage and of aeolian sand formations. In New Guinea, a first account of Pleistocene glaciation on Mount Wilhelm has been completed. A study of microrelief and vegetation banding has been made in the Alice Springs and Wiluna-Meekatharra areas.

Land forms have been studied in relation to soils of two areas. Cyclic land forms mapped near York in the Avon Valley of Western Australia have thrown new light on regional mapping by the Division of Soils. A study of the geomorphology of the Yass Catchment has been made in relation to an observed soil sequence and distribution, to determine which climatic conditions and land-forming processes prevailed when these soils were formed —in particular the possibility of Pleistocene peri-glaciation.

4. SYSTEMATIC BOTANY.

(Division of Land Research and Regional Survey.)

Botanical specimens are collected each year by survey units. Identifications are provided by the herbarium staff and duplicate specimens distributed to Australian and overseas herbaria. A study is being undertaken of the grasses of tropical Australia, with reference to their economic importance, and a taxonomic study of the genus *Ichnanthus* in Australia has been completed. A comprehensive and critical enumeration of New Guinea plants is being prepared with bibliography. Taxonomic studies for this area in co-operation with the Division of Forest Products are concentrating on forest species. Studies on the alpine flora of Mount Wilhelm, and on new species of *Dillenia* have been completed. A monographic study of the *Cunoniaceae* has been initiated and shows that current generic delimitations are unsatisfactory; a revision of seven genera in this family is nearing completion, following a visit by the Division's taxonomist to several herbaria in Europe and the United States of America.

5. CLIMATOLOGY.

(Division of Land Research and Regional Survey.)

In many underdeveloped regions in Australia, climatic factors are of primary importance in limiting development and productivity. The Climatology Unit studies climate-vegetation relationships to define and interpret the elements of climate affecting plant growth and production.

Investigations include climate-vegetation studies of spinifex (*Triodia basedowii*) and mulga (*Acacia aneura*) communities near Alice Springs. Special emphasis is placed on the water relationships of communities, and the proportion of the rainfall which enters the soil, and which is utilized by the plants, is measured and its influence determined. Microclimate is also studied so that significant differences between macroclimate and microclimate can be given quantitative expression, and the influence determined of microclimate on plant responses.

In the mulga experiment some of the primary results from water balance investigation are: (i) The grove-intergrove pattern of the mulga community is associated with differences in soil water penetration. (ii) A significant proportion (about 40 per cent.) of the rain falling on individual mulga trees is intercepted by the canopy and channelled down the trunks of the trees. (iii) Following rain, evapotranspiration is slow in winter owing to low temperatures and recurrent frosts. This is associated with very slow growth even by artificially watered trees. With cessation of frosts in spring, stored soil water is rapidly extracted and the trees become more active. (iv) The phyllode tissue is very resistant to desiccation, a diffusion pressure deficit (D.P.D.) of about 20 atm. being required to reduce the relative turgidity to 90 per cent., and of 60 atm. to reduce relative turgidity to 50 per cent. (v) After protracted periods of dry weather relative turgidity levels fall below 40 per cent., equivalent to D.P.D.'s in excess of 100 atm. Recovery of turgidity after rain takes up to four days if the preceding dry period had been severe.

The study of microclimate has not reached the same stage as that of water balance, but is conducted with two closely related aims: firstly, study of the physical microenvironment of mulga, and secondly, study of the energy balance of the mulga community, as the primary cause of observed microenvironment. Absolute radiation measurements are made with solarimeters; net radiative flux and soil heat flux is measured with net radimeters and soil heat flux plates designed by the Division of Meteorological Physics. This Division has also designed the fine-structure wet and dry bulb temperature elements for microclimate measurements.

6. HYDROLOGY.

(Division of Land Research and Regional Survey.)

Instruments and techniques are being developed for research in arid zone hydrology, and a survey method established for ground-water basins successfully tested in the Wiluna area of Western Australia.

Among instruments for measuring stream flow, a velocity-head rod has proved most suitable for rapid measurements by unskilled operators. For ground-water, the technique consists of measurements of rate of dissipation of dye in a borehole. Co-operation with the Division of Meteorological Physics has resulted in the design of a long-term recorder, now undergoing field tests near Canberra. Public authorities collecting rainfall and stream flow records have shown interest in this instrument, which offers the possibility of obtaining information from remote areas at very low cost.

The field investigation near Wiluna included the hydraulic conductivity and storage of ground-water, rates of recharge, rates of natural loss, the present safe draw from the aquifers, and the possibility of increasing the supply by artificial recharge. Of the two systems which have been used for irrigation, the small Lorna Glen aquifer was chosen for a detailed study and water-table contours only were determined for the large system east of Wiluna. It should now be possible to make some judgment of the irrigation potential of the Wiluna-Meekatharra region as a whole.

7. AGRICULTURAL ECOLOGY.

(Division of Land Research and Regional Survey.)

The compilation has continued of existing technical data on the Ord River project. Difficulties are experienced in obtaining economic data without which the full implications of technical findings cannot be estimated. From the review of technical data irrigation development in the Ord River plains must be based on crop production, although by-products such as oil cakes might affect animal production in the region.

Rice and oil crops (and later cotton) may provide a basis for development. From the purely technical point of view, development based on sugar cane production would be the most certain, but owing to over-production there are serious economic and political objections to this development.

Development of irrigation could take place in stages, each stage depending upon the success of the previous one. The agricultural and economic implications of the first stage based on the construction of a weir at Bandicoot Bar are being examined.

8. KATHERINE RESEARCH STATION.

(Division of Land Research and Regional Survey.)

(*a*) *Crops*.—Arable crop studies include: the agronomy of peanuts, grain sorghum, and cotton, and their place in farming systems.

In the second year of a peanut spacing and plant population trial, 2-ft. rows outyielded the standard 3-ft. row. Peanuts were cropped on the same land for the tenth year in succession without appreciable yield decline due to age of land. For the second year, introduced American hybrid sorghums outyielded the standard Hegari. Cotton variety trials were continued. Cotton sown on ridges gave no higher yield than cotton sown on the flat.

In the second year of comparison of crop performance on three soil types, red sandy soils of the region appear as suitable for agriculture as red loam soils. In a long-term comparison of rock phosphate and superphosphate, the residual effects of superphosphate were no longer apparent after five years, whereas rock phosphate still gave a yield response.

(*b*) *Pastures*.—In pasture, fodder crop, and cattle studies emphasis is placed on the integration of beef cattle fattening with arable farming and on the more efficient use of native pasture.

For the second year, cattle continuously grazing native pasture burned in the previous dry season made greater gains than those continuously grazing unburned pasture or those on rotational grazing.

Small amounts of high-protein supplement in the form of guar (*Cyamopsis tetragonoloba*) were found to be completely effective in preventing heavy losses in weight of cattle grazing native pasture in the dry season.

In a first test of intensive dry-season fattening, cattle receiving sorghum grain and peanut meal while grazing birdwood grass/Townsville lucerne pasture gained over 2 lb. per head per day for sixteen weeks.

(*c*) *Soil Nitrogen*.—Available soil nitrogen is a limiting factor in the Katherine region, and research effort is devoted to studies of soil nitrogen under arable crops and pasture.

Top soil nitrate in fallows fluctuates at a low level during summer and increases during winter. Decreases are due to leaching, and lead to subsoil nitrate accumulation of 500 lb. nitrate nitrogen per acre after six years' fallowing, and a corresponding decrease in organic nitrogen in top soil. The annual fodder crop bulrush millet recovers more sub-soil nitrate than any other crop. Leaching of winter-accumulated nitrate may be prevented by the incorporation of sorghum stubble, which immobilizes it and releases it at a later stage. In 1958-59 this practice gave a yield increase of 25 per cent. in grain sorghum.

(*d*) *Nitrogen Fixation by Non-symbiotic Micro-organisms*.—At the Microbiology Department of Sydney University methods are being developed for isolating nitrogen-fixing blue-green algae as pure cultures to study their nitrogen fixation. Nitrogen fixation in soil is also studied to determine the role of nitrogen-fixing micro-organisms.

9. KIMBERLEY RESEARCH STATION.

(Division of Land Research and Regional Survey.)

Work has continued at the Station on irrigated agriculture in the Ord area and the tropical monsoonal climate of northern Australia. Last season the rainfall was above average, mainly owing to two cyclones, one causing an exceptionally heavy rainfall of 21 inches in April.

(*a*) *Rice*.—Yields of about 2 tons per acre were achieved in both dry and wet season plantings, with some treatments yielding well over 3 tons per acre. A *japonica* variety grown in the dry season and an *indica* in the wet season responded markedly to deep placement of ammonium sulphate.

Introduction and selection of new varieties has continued, including selection of F.A.O. *indica* x *japonica* hybrids.

Fortnightly planting throughout the year of the main types of rice has shown that most varieties are highly specific in their planting season requirements.

In conjunction with the Station laboratory studies are being made at Canberra on the nitrogen uptake by *indica* varieties and on ammonia losses from the soil. Studies are undertaken at the Bacteriology Department of the University of Queensland of the decomposition of the residual rice straw and roots following ploughing in, under controlled conditions of soil moisture and temperature, together with the relationship between this and the accumulation and disappearance of nitrate.

(*b*) *Oil Crops.*—Experiments with oil crops included safflower, linseed, soybean, castor, and sesame. Further work on safflower confirmed its suitability as a dry-season crop. Yields were generally of the order of 1 ton per acre, with some treatments yielding 1½ tons per acre. No difficulties were encountered in the establishment of linseed, and in spite of serious *Heliothis* damage yields were recorded up to 1,700 lb. per acre. Premature shattering proved the main problem in the growing of soybean.

(*c*) *Cotton.*—Numerous varieties of *Gossypium hirsutum* and *G. barbadense* were introduced last season. Some of these show considerable promise, although a breeding programme may be necessary to obtain varieties suitable for local conditions. A serious outbreak of black-arm (*Xanthomonas malvacearum*) may be the main problem of cotton growing in the area.

(*d*) *Pastures and Fodder Crops.*—Results of work on " stand-over " fodders, and lucerne and clitoria pastures, were disappointing and confirmed that irrigation for this purpose is unlikely to be economic.

(*e*) *Cattle.*—In a supplementary feeding experiment with Wyndham blood and bone, elephant grass, clitoria hay, and safflower meal, only the last supplement produced significant weight grains. Under controlled grazing management, dry-season weight losses of young stock were negligible. Another trial indicated an extremely low age of mating of heifers under open range conditions.

10. Arid Zone Research.

(Division of Land Research and Regional Survey.)

Research in central Australia, based at Alice Springs, is devoted to ecological study of native pastures and their environment, to increase their productivity. This can be achieved in a number of ways, and the following are being attempted: (i) improved husbandry based on ecological understanding of the pastures and the effects of grazing, (ii) improvement of native pasture by seeding with more useful species, and (iii) reclamation of degraded communities.

The first requirement for reseeding native pastures is to find better species than the indigenous ones. Useful pasture species have been imported and along with native species are now being assessed in a plant nursery. The first important assessment is ability to persist in the climate of the area, which means ability to tolerate drought for considerable periods. Some species are promising but tests are incomplete. The nursery continues to develop as seed supplies of further species become available.

Reseeding experiments were commenced or continued in the mulga and spinifex areas using certain strains of buffel grass (*Cenchrus ciliaris*). Sowings were made in early and late summer, but as rainfall was inadequate no establishment was achieved in any of the land treatments used. Furrows continue to be successful in accumulating soil moisture and a more detailed study will be undertaken of furrow design and spacing.

Winter rains gave good germination in 1958 (and this has been repeated in the winter of 1959). However, the number of plants persisting one year later is so small that either the treatments must be regarded as unsuccessful or buffel grass itself is unsuitable in these areas. These plots are now being used for ecological studies of natural regeneration of spinifex and upland mulga communities after clearing and burning treatments.

The possibility of serious soil mineral deficiencies arises from this work. Marked response to phosphorus was found in pot tests with buffel grass, and further tests are in progress on type and placement of fertilizer for best responses. A trial was commenced on denuded areas of flood-plain pasture communities. Contour and checker-board furrows were successful in establishing stands of buffel and birdwood (*Cenchrus setigerus*) grasses after falls of rain even less than 1 inch.

XII. FISHERIES AND OCEANOGRAPHY.

1. General.

The aquatic resources of Australia's extensive coastal areas are of great national importance, and the Division of Fisheries and Oceanography is concerned with their study. The work of the Division includes the study of whales, the more important fish, crustacea, and shellfish, and is aimed at ensuring their economic use, and, where necessary, their management to prevent depletion of stocks. Fundamental to this study is an examination of environment to ascertain the variations in oceanographic conditions which affect biological production, and are, to a large extent, responsible for fluctuations in fish occurrence.

The work of the Division of Fisheries and Oceanography is described in this Chapter.

Division of Fisheries and Oceanography.—The main themes of the work of the Division have been fisheries biology, the physical and chemical oceanography of the Coral and Tasman Seas, fish behaviour, and biological production in the sea.

A new two-story wing added to the front of the main building was completed during the year, and provided biochemical and hydrological laboratories, a seminar room, and six offices for administrative staff.

The keel of a new barracouta research vessel was laid in January, 1959, and the vessel is almost complete. The barracouta investigation is being carried out in co-operation with the Commonwealth Interdepartmental Advisory Committee on Fisheries Development.

The hydrological facilities at the Eden field station have been increased to meet the needs of the tuna investigation programme.

U.N.E.S.C.O. provided funds in August, 1958, for a Conference in Australia on the Oceanography of the Coral and Tasman Seas. Delegates from the Institut Français d'Océanie, Noumea, the New Zealand Oceanographic Institute, Wellington, and the Division of Fisheries and Oceanography, Cronulla, and seventeen observers met at Cronulla. They discussed the possibility of co-operating in a study of the oceanography of the Coral and Tasman Seas.

The Thirteenth School in Marine Biology was held at the Division in May, 1959. Thirty-three students and members of staff attended from the Zoology and Biochemistry Departments of the Universities of Queensland, Adelaide, Sydney, and Tasmania. Lectures were given to senior students in Zoology at the Unversity of Sydney by Dr. G. F. Humphrey and by Dr. J. M. Thomson.

The Division acknowledges with thanks all assistance given during the year by universities, government departments, and other establishments both in Australia and overseas.

2. Operations of Research Vessels.

(Division of Fisheries and Oceanography.)

(*a*) *F.R.V.* Derwent Hunter.—The vessel carried out sixteen cruises and occupied 190 stations, of which about 100 were deeper than 1,000 m. The area covered was between 30 and 36° S. and east to longitude about 158° E. The cruises allowed data to be collected on hydrological structure and water mass composition, on the extent of carbon fixation (^{14}C method), on the qualitative occurrence of phytoplankton, on the concentration of plankton pigments, and on the qualitative and quantitative occurrence of zooplankton.

(*b*) *F.R.V.* Gahleru.—This vessel carried out 22 cruises in the Thursday Island area and east coast of Queensland area. These were concerned with collecting samples, stockpiling shell, and tagging about 900 specimens of *Pinctada maxima* for growth studies.

(*c*) *F.R.V.* Marelda.—This vessel is based on Eden. She made 61 traverses offshore to 24 miles, 34 from Eden, nineteen from Bermagui, five from Bateman's Bay, and three from Jervis Bay. Water samples were collected at stations 4 miles apart and returned to the Eden station for analysis. Tuna were trolled on all traverses, all were measured, and the smaller specimens were tagged. With the Kelvin Hughes Fisherman's Asdic it is possible to detect scattered or loosely schooled fish with echo sounding. Small schools of tuna, which were detected with the echo ranger, tended to disperse when subjected to repeated sound transmissions. For clearer fish detection a cathode ray tube was installed, which is sensitive enough to detect single fish, especially near the bottom. The thermograph recorder was used to locate temperature fronts.

(*d*) *F.R.V.* Jay Bee.—This vessel occupied the 50 m. and 100 m. stations off Port Hacking once each week for regular oceanographic work including the collection of samples for hydrology, carbon fixation, pigment determinations, bacteriology, phytoplankton, and zooplankton.

3. FISHERIES BIOLOGY.

(Division of Fisheries and Oceanography.)

(*a*) *Whales.*—A paper has been prepared on the determination of age in humpback whales using baleen plates, ovaries, and ear plugs. Baleen affords a useful means of age determination up to puberty (four to five years of age) but is of little use beyond this because of wear at the tip. The mean rate of ovulation in sexually mature female humpback whales is 1.1 per year. This can be used in estimating the distribution of ages in a large sample of females, but considerable individual variation in the rate of ovulation limits the accuracy of this method. The number of laminations within the cores of the ear plugs is the most reliable of the indirect methods of age determination in whales. Using the ear plugs for determining age, the age distributions have been compared of both sexes from samples of mature humpbacks from the west and east coasts of Australia. The population migrating along the west coast is at present composed of younger individuals than that on the east coast of Australia.

Data and material collected from humpback whales at all Australian whaling stations during 1958 were used in the preparation of a report for the Eleventh Meeting of the International Whaling Commission. The depletion of the population of humpback whales which winters along the west coast of Australia has continued and is now becoming critical for commercial operations. In most features the composition of recent catches from the east coast of Australia indicate that this population of humpback whales continues to be in fairly sound condition.

In October, 1958, three specimens of Bryde's whale (*Balaenoptera brydei* Olsen) were taken near Shark Bay, Western Australia. This is the first record of this species in Australian waters. Material was collected from sperm whales killed off Albany. Four of these, less than the minimum legal length (35 feet), were taken under special licence for research purposes. They were females, ranging from about 30 ft. 8 in. to 33 ft. 6 in. in length and were all sexually mature.

Marking of humpback whales continued in 1958, 174 marks being used on the east coast and 75 on the west coast of Australia. More than 1,000 humpback whales have been marked in recent years on the Australian coast. A record number of 21 marks was recovered at Australian whaling stations in 1958. Most of these had been fired into whales along the Australian coast, but one was from Foveaux Strait, New Zealand, while four had been fired by a Russian expedition, and one by a Japanese expedition in Australian waters. Seven Australian marks have been reported from humpbacks taken in Antarctic waters during February, 1959. Five of these had been fired off the east coast of Australia; one was recovered in Antarctic area V., and four in area IV. The remaining two had been fired off the west coast and were recovered in Antarctic area IV.

(*b*) *Sea Fish.* (i) *Barracouta* (Thyrsites atun).—The reading of barracouta otoliths has continued, and up to nine opaque zones recognized. The catch statistics for 1957-58 show a considerable reduction in the Tasmanian catch of this species. This was probably caused by the decreased demand following the closing of a fish cannery in December, 1957. The total Australian catch was comparable to the record low catches of 1940 and 1955-56.

(ii) *Tuna.*—At Eden (the centre of the tuna investigations) a close association has been noted between the seasonal appearance of the surface schools of southern bluefin tuna, and the seasonal changes of the water masses (see Section 5 (b) of this Chapter). The occurrence of southern bluefin tuna in New South Wales waters coincides with the movement of the "South-west Tasman" water mass, which moves north along the coast during June-September and then retreats south with variations in speed and location until late December or early January when it disappears, and is replaced by the summer hydrological pattern. When this change takes place bluefin no longer occur in the region, but are found in more southern waters.

As soon as the dominant overlying tropical water on the New South Wales coast is replaced by the South-west Tasman water in June the tuna appear either in small schools or scattered, and they move north with the colder water. They school in, or close to, regions where temperature discontinuities appear and the accumulations of the large schools, which are commercially exploited, appear where the South-west Tasman water mass builds up against the southward-moving tropical water.

An interesting change in the composition of the species taken by the trawl fishery in the Eden area was observed to be associated with the change from summer to winter hydrological patterns. A change from morwong to flathead in the catch was observed at the same time as the surface-schooling southern bluefin tune disappeared. However, the morwong return to the area approximately two months before the tuna appear, but the re-appearance of morwong occurs at the same time as the disruption of the thermocline between the overlying tropical water and the colder sub-Antarctic water.

(iii) *School Shark* (Galeorhinus australis).—Seventeen tags were recovered making a total of 378 returns and a recovery rate of about 6 per cent. Of the recent recoveries one from a shark, 23½ years old, which was free for nine and a half years, was of particular interest. This shark had grown at the rate of 3.5 cm. per annum.

(iv) *Gummy Shark* (Mustelus antarcticus).—Ten tags were returned from this species, raising the total recoveries from October, 1952, to date to 40 (7 per cent.). The ten were all from one batch of sharks tagged in July, 1954, near Goose Island, and were recaptured not more than 55 miles from the tagging locality.

(*c*) *Estuarine Fish. Lake Macquarie Studies.*—The scientific papers dealing with the Lake Macquarie survey have been completed and a general summary has been prepared.

(*d*) *Freshwater Fish. Trout Investigations.*—Work is in progress on the fishery of the southern region of Tasmania. A problem has arisen from this work which was considered to be worth further investigation, requiring the collection of additional material from a study of the variation of meristic characters. This has been completed, and it appears probable that in addition to the normal river population, part of which may visit the estuaries, there exists in Tasmania a second race of fish, present in small numbers, corresponding to the sea-trout of European waters. Also a study has been made of the yield of eggs from trout taken from three sources in Tasmania.

(*e*) *Fish Behaviour Studies.*—With the completion of the experimental laboratory for fish behaviour work, the task of fitting the laboratory and aquarium has gone on. It has been possible to hold mullet in the aquarium for prolonged periods of at least several months and an adequate algal diet has been devised. In experiments on the reactions of mullet to possible choices in salinity level the characteristic reaction of mullet of mature size was not so much a choice of any particular salinity as a tendency to examine any change. During such experiments, the mullet appeared to be excited, moving about at much greater speeds and with greater constancy than when in the acclimatization salinity. This cannot be interpreted as the result of irritation due to change, as water of the acclimatization salinity was available to them and the mullet entered the other salinities from the acclimatization salinity of their own volition.

(*f*) *Crustacea and Shellfish.* (i) *Western Crayfish* (Panulirus longipes).—A review of this fishery for the past eight years shows that the area fished, the number of men, the number of boats, and the number of pots have steadily increased. In 1952-53, 433 men, 151 boats, and 10,000 pots were operating, but in 1957-58 the numbers had increased to approximately 770 men, 278 boats, and 30,000 pots. The catch per man, and the catch per boat, did not vary greatly, but the catch per pot dropped to about 600 lb. in 1957-58 as compared to 800 lb. in 1952-53. There was considerable variation in different areas, with those south of latitude 30° S., the areas fished consistently for the longest term of years being the most affected. The crayfish stocks appear to be meeting satisfactorily the strain imposed by increased fishing pressure. In that period the catch has increased from about 7,000,000 to about 13,500,000 lb.

(ii) *Southern Crayfish* (Jasus lalandii).—The surface dispersion of the planktonic larvae of this species of crayfish in South Australian, Bass Strait, and Tasmanian west coast waters is being studied. To date, 3,100 weighted sealed drift bottles have been individually standardized for flotation in water of chlorinity 19.40°/oo, and temperature of 13° C. (σ_t 26.40). One hundred and fifty bottles have been released each month from coastal vessels off Cape Northumberland (South Australia), off south-west of Cape Otway (Victoria), and off Mount Hemmskirk and abeam of West Point (Tasmania). About 15 per cent. have been returned, more from the first two release points. These recoveries indicate an easterly surface drift through Bass Strait from September to November and a reversal in direction to the west from December, with a tendency to the north-west off the South Australian coast. Underwater observations on small crayfish were made at Port MacDonnell (South Australia), Cape Sorell (Tasmania), and Hobart. The 0+ group have been difficult to find, but from the collections made the modal carapace size of one-year crayfish is fixed at about 15 mm., and of two-year at about 33 mm. In January, 2,200 undersized crayfish were punch marked and released at Cape Sorell. Evidence from 98 recoveries of crayfish tagged in previous years has shown that the male rate of growth was higher than that for females.

(iii) *Pearl Oysters* (Pinctada *spp.*).—Growth studies have been continued. More than 900 specimens of *Pinctada maxima* have been tagged. Supplies of *P. maxima* have been stockpiled for future investigation.

(iv) *Pacific Oyster* (Crassostrea gigas).—Spatfalls of this species have been located near the mouth of the Tamar River, which indicates that the species may now be regarded as acclimatized in northern Tasmanian waters. Control of the stocks of Pacific oysters in Tasmania and Victoria has been offered to the departments administering fisheries in the States concerned.

4. TAXONOMY.

(Division of Fisheries and Oceanography.)

A further six numbers of the Handbook of Australian Fishes have been published in the *Australian Fisheries Newsletter;* 30 numbers in this series have now been issued covering fishes from the Cyclostomata to the family Carangidae in the order Perciformes. The Checklist of New Guinea Fishes appeared in December 1958 as volume 10 (4) of the *Papua and New Guinea Agricultural Journal.* This completed the first stage in the investigation of New Guinea fishes.

5. HYDROLOGY.

(Division of Fisheries and Oceanography.)

(*a*) *Oceanic.*—Study of the East Australian Current was continued with regular extensions of sampling to Lord Howe Island. A line of deep stations along the 155° meridian from latitude 13° S. to 28° S. was worked in January, 1959, from the Japanese Training and Research Ship *Umitaka Maru.* Temperature, salinity, oxygen, and inorganic phosphate values were obtained.

(*b*) *Eden.*—The hydrology programme worked in conjunction with the tuna investigations has been expanded and the annual succession of water masses has been followed. In the summer an upper layer of warm water from the surface to about 50 m. overlies a layer of cold water from 50 m. to the bottom. The upper layer is a complex mixture of varying proportions of West Central South Pacific, South Equatorial, and Coral Sea waters. The underlying layer is almost certainly Sub-Antarctic surface water which has submerged at the Sub-tropical Convergence. In the winter three water types are present. The whole continental shelf is covered by water provisionally called " South-west Tasman ". The origins of this water type are not yet certain, but it derives from further south and moves up the southern New South Wales coast as far as Jervis Bay, with velocities of about 1 knot. There are numerous eddies, sometimes recurving in a southerly direction off Montagu Island and Jervis Bay. These eddies and counter currents contain warmer off-shore surface water in patches and produce complex temperature fronts.

(*c*) *Analytical Methods.*—Investigations are being carried out on the changes in the three phosphate fractions (particulate, dissolved organic, and inorganic) on storage. Results so far are complex, but some contradictions may be due to the use of aged, and thus almost sterile, sea-water. Greater loss of total phosphate occurs when a sea-water sample is stored in the light rather than in the dark. Acidification and scrubbing of the sample bottle will restore most of the lost phosphate into solution. Filtration of the sample through a millipore membrane prevents changes in the phosphate distribution. An aerated, stored sample appears to accumulate dissolved organic phosphorus, with little change in total phosphorus, at the expense of particulate and inorganic phosphorus. Loss of total phosphorus appears to occur when the sample is stored without access to air, with death of the phytoplankton, and a subsequent rise in the epiphytic bacterial population.

6. PHYSICAL OCEANOGRAPHY.

(Division of Fisheries and Oceanography.)

The results from the calculation of surface currents and volume transports relative to 1,000 metres from temperature and salinity data collected by F.R.V. *Derwent Hunter* show that the south-flowing East Australian Current usually turns away from the coast just north of Sydney. When it is about 150 miles offshore, it turns further to the north-east or to the north.

Monthly mean sea-levels from nineteen ports on the Australian mainland and adjacent islands were collected as part of the Division's contribution to the International Geophysical Year. The values have been sent to world data centres. The relation is being examined between sea level, atmospheric pressure, and water density during this period. A statistical analysis of daily mean sea-levels and corresponding atmospheric pressures at Sydney, Coff's Harbour, and Lord Howe Island is being carried out, using the high-speed computer at the University of New South Wales.

Monthly charts of the surface currents in the Coral and Tasman Seas have been constructed, based on ships' observations. These charts give information on the seasonal fluctuations of the circulation in this region, and allow conclusions to be drawn on the interaction of the different branches of the currents. The positions of the Subtropical Convergence and Tropical Convergence could be determined. An area of divergent movements and upwelling exists as a permanent feature in the Coral Sea. The observed departure of the East Australian Current from the coast of New South Wales south of 32° S. could also be confirmed and is a permanent phenomenon, being related to a divergent flow pattern. At strong southerly winds the East Australian Current is accompanied by a counter current, or vanishes completely.

An improved salinity meter for laboratory use has been designed. The new instrument uses an inductive conductivity cell, which avoids the need for metallic electrodes in direct contact with the sample. The accuracy should be about ten times as high as that obtained with the first model of salinity meter, or by the traditional titration method.

A pressure transducer has been designed for measuring the depth of an instrument below the sea surface. The transducer has a number of advantages over commercially available transducers, and should find other applications in the measurement of pressure, especially where telemetering is involved. The instrument is being patented.

7. PRODUCTIVITY.

(Division of Fisheries and Oceanography.)

During this year the separate productivity cruises of F.R.V. *Derwent Hunter* were replaced by twelve longer, more general cruises in which the measurement of carbon dioxide uptake by the ^{14}C method was done in conjunction with normal hydrological stations, phytoplankton studies, and plankton pigment measurements. These stations included those on the Port Hacking section line and additional ones between Lord Howe Island and Coff's Harbour.

8. ZOOPLANKTON.

(Division of Fisheries and Oceanography.)

A flume tank has been constructed so that the flow meters of Clarke-Bumpus samplers can be calibrated in terms of the quantity of water passing. The water can be pumped through the tank simulating towing speeds of up to 3 knots.

During 1959 the amount of zooplankton at Port Hacking 100 m. station averaged approximately 167 mg./cu.m., and at the 50 m. station 261 mg./cu.m. The level reached a maximum in February of 348 mg./cu.m. at the 50 m. station. At Eden maximal values were reached in October-November, 1957, April-May, 1958, and September, 1958, with an average of 93 mg./cu.m. at the 16-mile station. At a 24 hr. station in the Eden area worked in 110-130 m. in April, 1959, the mean value was 146 mg./cu.m., at 107 m. the mean plankton biomass was only 30 per cent. of that at 98 m., showing a marked discontinuity of distribution. This coincided with a region of a weak thermocline. During some periods of this 24-hour cycle the plankton biomass became concentrated at certain points to over 300 mg./cu.m.

The total nitrogen content of the local zooplankton varies from 2-20 mg. per g. (wet weight) with a mean value of 9 mg./g. This corresponds with determinations by overseas workers. However, the total phosphorus at a Port Hacking station in April had a mean value of 0.41 mg./g., which is only half that recorded by other workers. The N/P ratio of this series was 24. There was a gradual rise between December and April in the total nitrogen content of the plankton samples at Port Hacking stations.

9 PHYTOPLANKTON.

(Division of Fisheries and Oceanography.)

Phytoplankton collections made from H.M.A.S. *Warrego* in the spring showed that the water inside the Barrier Reef contributes little to the phytoplankton of the eastern New South Wales waters. However, collections made in the Coral and Tasman Seas indicate that some elements of the phytoplankton of the New South Wales coast are derived from source water masses, while certain elements are not so derived.

10. MARINE FOULING.

(Division of Fisheries and Oceanography.)

Investigations on rearing fouling larvae and observing their settling reactions have been continued. Preliminary experiments conducted at the Marine Biological Station, University College of North Wales, showed that it was possible to rear the introduced Australasian barnacle *Elminius modestus* Darwin to the settling stage in the laboratory during midwinter when natural settling was not taking place. Yields would presumably be higher during spring to autumn when this species normally settles. Five consecutive experiments yielded 3,431 settled cyprids. The settling reactions of the tubeworm *Spirorbis borealis* Daudin were examined at the same locality. The complex exploratory patterns shown immediately prior to settlement were modifiable; larvae prevented from settling for long periods of time became progressively less discriminating in the choice of a settling site. Direct observations have commenced on the effects of heavy metal ions on settling larvae.

11. BIOCHEMISTRY.

(Division of Fisheries and Oceanography.)

Methods were studied for the isolation and identification of chloroplast pigments. A two-dimensional paper chromatographic method was developed which gives complete separation of chlorophylls *a*, *b*, and *c*, carotenes, and several groups of xanthophylls. The pigments are later identified by their absorption spectra after elution from the chromatogram.

Routine determination of pigments has continued at the 50 and 100 m. station off Port Hacking, and determinations made in the Coral and Tasman Seas and the Indian Ocean wherever carbon fixation has been estimated.

12. BACTERIOLOGY.

(Division of Fisheries and Oceanography.)

Preliminary work has begun on the study of marine bacteria. About 30 species have been collected, and two species selected for detailed study.

XIII. FOOD.

1. General.

Being a major food producing country, Australia has a special interest in the preservation of food during transport. Even the more perishable foods are now being conveyed great distances between producer and consumer. Being situated far from the main food importing countries, and having long hauls between capital cities in each State, food preservation and transportation are important factors in Australian rural economy.

The Organization's work on food is undertaken chiefly within the Division of Food Preservation and Transport with its main laboratories at Homebush, New South Wales, and branch laboratories at Brisbane (meat); West Gosford, New South Wales (citrus fruits); Hobart (fish. apples, and berry fruits); and at the Botany and Biochemistry Departments, University of Sydney (plant physiology and physical chemistry). The work of the Division is described in Sections 2-11 of this Chapter. Work on manufacture of dairy products is carried out by the Dairy Research Section at Highett, Victoria (see Section 12 of this Chapter).

Work on dried vine fruits is in progress at the Commonwealth Research Station (Murray Irrigation Areas). Merbein, Victoria (see Section 13 of this Chapter). The report of the newly formed Wheat Research Unit is described in Chapter III., Section 22.

Division of Food Preservation and Transport.—Investigations on processing and storage of dehydrated meat terminated in November 1958. The leader of the group will be spending about one year in analysis of results and in completing reports.

During the past two years an officer of the Division has been working at Cambridge and Wantage (England) on the effects of ionizing radiations on foods. This officer returned to Australia early in 1959 and shortly afterwards started investigations in this field, initially on the killing of eggs and larvae of Queensland fruit fly in citrus fruits.

An electron microscope has been installed in the Zoology Department, University of Sydney, and will be operated jointly by the Division and the Animal Genetics Section.

Close co-operation continued with several university departments, Government laboratories, and industry. Through its Meat Research Laboratory, Brisbane, the Division organized surveys of the condition of chilled beef at loading in Queensland and at discharge in the United Kingdom. These surveys aim to study excessive desiccation of meat and, if necessary, to indicate remedial measures. The Australian Meat Board, the Refrigerated Cargo Research Council, the Low Temperature Research Station (Cambridge), shipowners, and meatworks are co-operating in these surveys, which will probably take about twelve months to complete.

Dr. R. N. Robertson, Assistant Chief, was granted leave of absence for one year to take the position of Visiting Professor of Horticulture at the University of California, Los Angeles. Dr. Robertson expects to return to Australia in September, 1959.

Dairy Research Section.—Main activities of the Dairy Research Section include mechanization of cheese manufacture, development of new products from milk, examination of manufacturing and keeping quality problems of dairy products, improvement of packaging, and investigation of flavour chemistry.

Dr. E. B. Collins of the University of California spent some weeks in the Section working on cheese starter cultures. Other overseas visitors included Mr. W. R. Trehane, Chairman of the Milk Marketing Board of England, Messrs. A. K. R. McDowell and D. W. King of the Dairy Research Institute, New Zealand, Dr. F. B. Shortland of the Fats Research Laboratory, New Zealand, and Mr. M. R. Chandrasekhara of the Central Food Technological Research Institute, Mysore, India. Mr. J. Czulak returned to duty after a period of study in Europe where he worked particularly on the soft cheeses.

The Section co-operated in many projects with the State Departments of Agriculture. Close interest was maintained in work on milk proteins and conductivity measurements on milk at the University of Sydney. The Australian Dairy Produce Board contributed to the Section's finances and together with other industrial organizations such as the Australian Cheese Manufacturers' Federation, the Australian Casein Manufacturers' Association, and the Queensland Butter Marketing Board, joined in many activities.

2. Physics.

(Division of Food Preservation and Transport.)

(*a*) *Canning Processes.*—Work on the contribution of the cooling phase to sterilization of canned foods has now been completed and results are being summarized for publication.

(*b*) *Freezing Points of Fruit.*—Pears are often stored at a temperature close to their freezing point and freezing injury has occurred at times. Consequently precise measurements are needed of freezing points.

It has been commonly believed that the freezing points of many living plant tissues are substantially lower than those of killed or disrupted tissue, and pieces of living tissue have generally been used to measure freezing points of fruit. The true freezing point of living pear tissue has now been shown to be very close to that of disrupted tissue. (Turgor pressure presumably causes a very small depression of freezing point of living tissue.) The lower apparent freezing points measured with pieces of tissue are evidently the result of balance between heat transfer to the cooling medium and relatively slow movement of water to ice crystals growing in intercellular spaces, leading to release of latent heat on solidification.

(*c*) *Evaporation from Fruit in Cool Storage.*—Evaporation properties have been measured of apple cucumbers, and several varieties of peaches, pears, and apples. Factors governing loss of water from fruit packed in boxes are being studied using Packham's Triumph pears as the main experimental material. Convection within the box contributes significantly to the transfer of water vapor under certain conditions.

(*d*) *Water Relations of Food.*—Data have been obtained for materials rich in protein to assist in design and interpretation of experiments in freeze drying and dehydration in a stream of hot air.

(*e*) *Colour Measurement.*—Study has continued of simple objective methods of colour grading with tomato juice as the main experimental material.

(*f*) *Measurement of Relative Humidity.*—Applications of anodized aluminium probes are being studied for determination of relative humidity of air. Applications in studies of dehydration have received most attention so far.

(*g*) *Freeze Drying.*—In conventional freeze drying, drying proceeds far beyond sublimation of the ice frozen out. Encouraging results have been obtained in controlling the final water content. Close control of the final drying stages may have important applications in the freeze drying of microorganisms.

3. Food Chemistry.

(Division of Food Preservation and Transport.)

(*a*) *Volatile Products of Apples.*—Volatile products are related to flavour, control of ripening, and the storage disorder superficial scald. Ethylene from apples was found comparatively free of higher olefines up to hexene. Volatiles which absorb ultraviolet radiation are being investigated.

(*b*) *Control of Superficial Scald.*—Work continues on control of scald by diphenylamine and related substances and by mineral oil fractions. The effect of diphenylamine on volatile production is being investigated.

(*c*) *Lipids of Fruits.*—The natural lipid coating of apples (which affects metabolism of stored fruit through control of gas exchange) and the lipids of the avocado (a fatty fruit) are being investigated. The more volatile acids of the apple cuticle oil are being identified, and distillation of the hydrocarbons has shown the presence of sesquiterpenes. Acetone-soluble polar lipids of the avocado have been separated by adsorption chromatography into nineteen distinct substances. Similar lipid fractions have been shown to be present in ox liver and in sheep and human blood serum.

(*d*) *Lipoproteins.*—Storage behaviour of many foods is influenced by intracellular structures in which lipoproteins play an important part. Work commenced (in association with protein chemistry studies) on the nature of the binding of lipid to protein in lipovitellin and the influence of lipid on the physical properties of protein.

(*e*) *Isomerization of Unsaturated Fatty Acids.*—This reaction has application in lipid analysis. The improved isomerization with potassium *tert.*-butoxide was studied kinetically and a theoretical analysis of the data is being attempted.

(*f*) *Anaerobic Decomposition of Ascorbic Acid.*—This reaction is the one concerned in destruction of vitamin C in stored canned foods. Fairly complete data have been obtained on production of furfural over a range of pH. Furfural is comparatively stable at pH 6, and its negligible production from ascorbic acid at this pH is still unexplained. Paper chromatography with butanol-acetic acid has shown the formation of an unknown acid of high R_F value.

(*g*) *Chemistry of Non-Enzymic Browning.*—Browning of foodstuffs during storage is a serious cause of wastage. Chemical investigations on browning have been in progress for several years, and considerable progress has been made in elucidating the chemical reactions involved.

(i) *Chemical Pathways.*—The first steps in "Maillard" or non-enzymic browning reactions in aldose-amine systems are the formation of glycosylamines which undergo the Amadori rearrangement to give ketose amines. Ketose amines have been shown to react further with aldoses to give diketose amines which decompose rapidly, regenerating the ketose amine and giving a reactive dicarbonyl compound. A diketose amine has been isolated pure and crystalline, and the structures and chemical properties of the dicarbonyl compounds are being studied.

The foregoing reactions provide a mechanism for the conversion of aldoses to more reactive dicarbonyl compounds and explain the partially catalytic role of amines in non-enzymic browning reactions.

(ii) *Kinetic Studies.*—The rates of formation of colour and fructose amino acids have been determined in mixtures of glucose and different amino acids. Those rates agreed with those previously calculated from rates of disappearance of amino acids from stored dried fruit. Formation of fructose glycine was shown to be catalysed by anions of weak acids such as malate, citrate, or phosphate, but bisulphite had no catalytic action. Rate constants and activation energies were determined for some of these reactions.

(iii) *Inhibition.*—Sulphur dioxide and bisulphites are used to inhibit non-enzymic browning in foods. Crystalline addition compounds have been isolated of a number of aldose sugars and sodium, potassium, and amine bisulphites. Chemical properties and reactions of these compounds have been studied. Their stability in aqueous solution indicates that such addition compounds may protect the sugars and thus inhibit further reactions leading to pigment formation. Other reactions causing the disappearance of bisulphite in stored sulphured foods are being investigated.

(*h*) *Protein Chemistry.*—Studies continued of aggregation and conformation (or denaturation) changes in proteins. The main protein of egg white, ovalbumin, has been examined in the ultracentrifuge and by viscosity and optical rotation measurements, to investigate the reactions which occur on heating. Similarly, the effects of temperature have been studied on solutions of the two closely related milk proteins, β_A- and β_B-lactoglobulin, and significant differences in association behaviour have been found. Urea, which causes mainly conformation changes, has been used in a study of denaturation of a single type of bovine haemoglobin.

Further work on the freezing of fish muscle proteins has shown the need for better characterization of the individual proteins, myosin and actin, and their complex, actomyosin. A method was developed for preparation of pure myosin and measurements are continuing of size, shape, and electrophoretic behaviour in a variety of solvents. Preparation of actin, in its "natural" state, without using an organic solvent, has been attempted, so far unsuccessfully. Further studies have been made of size and shape changes of actomyosin, and the dissociating or disaggregating effects of high salt concentration and low pH (which may occur on freezing) have been confirmed. These measurements are being continued to give information on the structure of actomyosin and the actin-myosin interaction. The problem has been further studied of defining conditions of salt concentration, pH, and protein concentration during freezing and thawing of actomyosin. A recording dilatometer was constructed for measuring the ice formed at different temperatures during freezing of a protein solution.

The investigation continued of the different casein fractions of milk and their participation in clotting by rennin.

(*i*) *Polarography.*—Various electrodes are being examined for use in determination of sulphydryl in proteins. In collaboration with the Physics Section, an attempt has been made to develop a simple recording method of square-wave polarography.

4. MICROBIOLOGY.

(Division of Food Preservation and Transport.)

(*a*) *Water Relations of Micro-organisms.*—Studies continued of the relationship between cell composition and water activity of the growth medium. In one moderately halophilic and two non-halophilic strains, internal concentrations of sodium, potassium, amino acids, and inorganic phosphate increased as the water activity of the medium was reduced by addition of sodium chloride. Potassium or amino acids predominated in the non-halophilic organisms, while sodium predominated in the halophile.

The suggestion was confirmed that among non-halophilic bacteria a high level of potassium in cells grown in low-salt medium was related to high salt tolerance. The water contents of these organisms were similar (about 1.5 ml./g. dry weight) when harvested from low-salt medium. Among non-halophilic bacteria, those with the highest total internal concentrations of low molecular weight solutes appeared to be the most salt tolerant. In view of the apparent importance of sodium, potassium, and amino acids in controlling the internal osmotic environment of bacterial cells, studies commenced of the effects of various physical and chemical treatments on their accumulation and retention.

(*b*) *Bacterial Spores.*—Studies on the permeability of spores to water continued and studies commenced with solutes of differing particle size (sodium, potassium, and phosphate ions; sucrose, insulin, and dextran). Tests with heavy water and spores of four organisms confirmed that heavy water in the external medium mixes freely with all or nearly all of the water of the spore. These studies have been discontinued.

Smaller particle solutes added to the external medium also appear to mix freely in all the water contained by the spore. Further, space in the spore available to water and small solutes appears to be all the space of the spore except that of the dry matter. Studies continue on the permeability of spores to solutes.

Studies commenced of the resistance of spores to ionizing radiations using the radioactive cobalt facility at the University of New South Wales. The main aim was to obtain quantitative relationship between radiation resistance and spore water content. Results for spores of two organisms differing widely in heat resistance have shown that radiation resistance was similar for both organisms, and did not vary very greatly between the different water levels tested. The experiments are continuing.

Comparative studies commenced on the chemical composition of spores having a wide range of heat resistance.

(*c*) *Drying of Micro-organisms.*—Studies continued of factors affecting the death of micro-organisms during and after drying. Drying in the presence of certain sugars has, for some time, been known to reduce death. It has now been found that sugars may be either beneficial or detrimental according to the temperatures at which drying proceeds. The rather complicated relationship between solutions and drying temperatures suggests that these factors may only be of indirect importance. Results of storage experiments continue to support the hypothesis previously advanced that an important cause of death during dry storage is chemical reaction between aldehydes and ketones and cellular protein. Results of several other storage experiments have been analysed and await further condensation for publication.

Recent experiments have concerned storage in different gases and chemical changes occurring during storage. Production of aldehydes and ketones during storage under the driest known conditions has been demonstrated. Micro-organisms which survive drying and storage may be destroyed when water is restored to the dried cells, and some of the factors have been studied affecting destruction during rehydration.

5. Meat.

(Division of Food Preservation and Transport.)

(*a*) *Control of "Drip" from Thawed-out Frozen Meat.*—Efforts to control drip from frozen meat after thawing have concerned infusion of sodium chloride and sodium pyrophosphate into meat by artery and muscle pumping. When water without dissolved solutes is pumped into hinds to the extent of 10 per cent. of the weight most of the water appears as increased drip when the meat is frozen and thawed. By using combinations of sodium chloride and sodium pyrophosphate in the pumping fluid the amount of drip can be reduced below that of untreated meat. The optimum composition of the pumping fluid is being determined in relation to the solubility relations of the two salts and to salt flavour produced in the cooked product.

(*b*) *Tenderizing Processes.*—The nature of the post rigor changes which take place in nucleotides and which run parallel with development of tenderness are being further examined to determine whether the major pathway to the production of hypoxanthine lies through inosine. The temperature dependence of the individual reactions is being examined.

(*c*) *Thermal Properties of Carcasses.*—Study continued of temperature distribution within beef carcasses and investigation included the freezing of meat in carton packs. Similar studies have been carried out on meat held at temperatures just below the freezing point of meat tissue. Preliminary data suggests that supercooling occurs for limited periods at a number of isolated points, but during the period corresponding to normal shipment of chilled beef to Great Britain equilibrium tends to occur between the ice and the residual tissue.

(*d*) *Bacteriological Studies.*—Studies continued of the effect of carbon dioxide on metabolism in various species of psychrophilic organisms and the effect on individual oxidative reactions. No single oxidative reaction is involved. Rates of nucleic acid synthesis are inhibited to the same extent as overall growth rates. Attempts to distinguish between protein synthesis and oxidative reactions as the mechanism of inhibition have led to anomalous results. Slaughter-floor hygiene has been subjected to intensive study. Efficiency of carcass wiping as a means of reducing bacterial contamination is being re-examined and compared with recently adopted techniques of pressure spraying. Sterilization of animal hides before slaughter was studied and chemical aerosols investigated for sterilization of air.

(*e*) *Effects of Ozone.*—Earlier work on reaction between meat tissue and ozone was extended to low ozone concentrations. Initial specific ozone uptake of lean tissue is independent of ozone concentration but rate of decrease of specific ozone uptake decreases with decrease of ozone concentration. At low ozone concentration specific uptake by surface tissue decreases with increasing fat concentration.

(*f*) *Freezer Burn Investigations.*—Prefreezing loss of moisture and dipping in various concentrated solutions have been investigated and their effects studied on subsequent loss of weight necessary to produce freezer burn on beef livers. Reduction in rate of onset of freezer burn can be achieved by ensuring some evaporation during freezing. Even more effective control can be obtained by dipping treatments, but little advantage is obtained by combining treatments. In all cases control of freezer burn is more difficult, the higher the liver fat content. Similar studies are now being applied to kidneys.

Histological examination of damaged tissue reveals that cavities in damaged tissue do not arise directly from sublimation of ice crystals, but condensed tissue layer develops as ice crystals sublime, and cavities arise within the condensed layers as evaporation continues.

(*g*) *Nitrite Discoloration of Carcass Meat.*—Brown discoloration of exposed muscle surfaces and bleaching of adjacent fatty tissues of beef and mutton carcasses during chilled storage has been found to be due to the action of nitrite. Contamination of carcasses was due to condensed water falling from the ceiling; these drops contained nitrite. Discoloration may also be produced by oxides of nitrogen liberated from water flowing over battery cooling coils. In each case nitrous acid was produced in the water by the action of bacteria of the genus *Nitrosomonas* on ammonia derived from the refrigeration system. Periodical chlorination is effective in controlling these micro-organisms and in preventing discoloration of carcasses.

6. Fish.

(Division of Food Preservation and Transport.)

(*a*) *Frozen Storage of Prawns.*—The effect of glycerol on changes in texture and colour of the flesh of whole and peeled prawns during frozen storage has been studied.

(*b*) *Spoilage of Fish Products.*—Various forms of spoilage in fish products have been investigated.

7. Egg Investigations.

(Division of Food Preservation and Transport.)

(*a*) *Disorders in Eggs.*—Ingestion by hens of leaves and seeds of many plants from the order *Malvale* gives rise to "pink-white" disorders in eggs. Two related acids, malvalic and sterculic, are the active principles in plants causing these disorders. The effects of ingestion of small amounts of each acid have been clearly established. The predominant active principle in cottonseed oil, as in oils from *Malva* spp., is malvalic acid.

Chemical studies have shown that malvalic acid is probably ω-(2-*n*-octyl-*cyclo*prop-1-enyl)-heptanoic acid.

(*b*) *Hatchability*.—Ingestion of small amounts of sterculic acid by hens produces a high level of infertile eggs and completely inhibits hatching of chickens from the remaining fertile eggs.

(*c*) *Egg Quality*.—Decline in internal quality of eggs at various stages during the period of marketing within Australia is being examined.

8. FRESH FRUIT AND VEGETABLES.

(Division of Food Preservation and Transport.)

(*a*) *Plant Physiology and Biochemistry*.—The respiratory pathways and the electron transport chain of plant mitochondria were further characterized. Attempts to study the ionic content of mitochondria during salt accumulation by cells showed need for more thorough investigation of the permeability of the particles.

Biophysical studies continued on cells of *Chara australis*, with particular attention to ion exchange with the cell wall and vacuole. Measurements of ionic fluxes together with those of electric potential difference and resistance were made in collaboration with the Division of Plant Industry. Potential difference and electric resistance appear to be associated with the external cytoplasmic boundary and resistance to ion exchange largely with the tonoplast.

Peas were again grown in the phytotron at the California Institute of Technology to provide additional data on the effects of temperature on growth and starch and sugar content. These experiments should provide information on the conditions necessary for the development of high quality peas.

Further investigations were carried out on the enzymes involved in plant sucrose synthesis. Nucleoside diphosphokinase which forms uridine triphosphate (from which uridine diphosphoglucose, and hence sucrose, are synthesized) was isolated from pea seeds and other plant tissues and its properties studied. Investigations were completed on the properties of phosphatase from pea seeds which hydrolyses glucose 1-phosphate directly. This enzyme attacks other phosphoric compounds and may be of considerable metabolic importance as a control mechanism because of the pronounced inhibition of enzyme activity by inorganic phosphate.

Recent work indicated that guanosine nucleotides may be important in carbohydrate metabolism and other metabolic processes, and investigations were commenced on formation in plant tissues of guanosine compounds from the adenosine series. The probable first step in this reaction sequence is conversion of adenosine monophosphate to inosine monophosphate. A preparation of the enzyme responsible for this reaction was obtained from pea seeds.

Previous investigations established that aerobic inhibition of glycolysis (Pasteur effect) in pea seed extracts was due to reversible inactivation of glyceraldehyde 3-phosphate dehydrogenase (GPD). Mechanisms underlying this effect were studied and two processes were found to be involved. One was the non-enzymic, metal-catalysed oxidation of protein sulphydryl groups by oxygen, and the other was the enzymic reduction of protein disulphide groups (including those of GPD) by reduced di- or triphosphopyridine nucleotide. The enzyme catalysing this reaction was found in a number of plant tissues, and it was purified from pea seed extracts and its properties studied. Experiments on changes in phosphoric esters in intact pea seeds during the Pasteur effect provided evidence consistent with inhibition of the GPD reaction of glycolysis.

Phosphorylated compounds play a major part in respiratory and synthetic processes. Several additional phosphorylated compounds in pea seed extracts were isolated and identified and the nucleotides of pears were studied by paper chromatography.

Studies continued on the physiology of fruit development and maturation using apples from Stanthorpe, Orange, Griffith, and Tasmania. This co-operative project with the Division of Plant Industry may provide a useful approach to assessment of the best maturity for harvest. Physiological differences between fruit with large and small cells were further studied with Tasmanian Jonathan apples from thinned and unthinned branches of the same trees.

Investigations continued on processes of fruit development, maturation, and ripening of Williams pears from Bathurst Experiment Farm. Physiological, morphological, and anatomical changes were followed.

(*b*) *Fruit Storage and Related Problems.* (i) *Controlled Atmosphere* (*C.A.*) *Storage of Apples and Pears.*—Investigations continued of carbon dioxide and oxygen levels in relation to disorders and fruit quality in the variety Granny Smith. Superficial scald was unusually severe in 1958 and was not affected by various storage atmospheres. When controlled with diphenylamine (DPA) the best atmosphere for long storage of Granny Smiths was 5 per cent. carbon dioxide and 2½ per cent. oxygen. This atmosphere has also given best results with pears, greatly increasing storage life.

(ii) *Superficial Scald.*—Very satisfactory control was again obtained by preharvest spraying with DPA. Even following post-harvest application of sufficient DPA to inhibit severe scald, residues in fruit after cool storage were low. A quantitative relation has been established between DPA taken up by the fruit and degree of scald control.

(iii) "*Polythene*" *Film Box Liners as a Storage Aid.*—Fruit of the Williams, Packhams, Bosc, and Winter Cole pear varieties precooled before packing kept excellently in sealed "Polythene" liners and much longer than is possible by ordinary methods. "Polythene" liners are now being successfully used commercially for pears and some apples. When precooling is not practicable slight perforation of the liner is desirable to avoid risk of fruit injury.

When increased scald was controlled with DPA Granny Smith apples stored particularly well in "Polythene", but the liners increased breakdown in susceptible lines of Jonathans and Delicious.

(iv) *Tree Nutrition and Fruit Quality in Apples* (*Co-operative Investigations with Chemist's Branch, New South Wales Department of Agriculture*).—This study was continued during the 1958 season with the variety Delicious. Nutritional status was determined by analyses of leaves and fruit, and quality of fruit was assessed by means of cool storage and tasting tests. There were differences between growers in both nutrient content and fruit quality, but the relation between the two was not clear, although not inconsistent with previous findings and published data. It was also apparent that methods of sampling are of critical importance.

(v) *Spray Residue Removal* (*Co-operative Investigations with Chemist's Branch, New South Wales Department of Agriculture*).—Residues of lead arsenate on apples and pears can be removed in a bath of weak acid. Preliminary trials indicated the possibility of removal of DDT with a double bath in a weak acid and an alkaline detergent. Because of delays in manufacture of a special washing machine further work was not possible on removal of residues of pesticides. Survey continues of residue levels on apples and pears following various common spray programmes, and so far only lead arsenate, DDT, and late sprays of mercury seem likely to present a residue problem at harvest.

(vi) *Control of Wastage in Citrus Fruit.*—The previously developed sodium orthophenylphenate "rinsed" treatment which gives excellent protection against mould in oranges for periods up to three-four weeks is now widely used in commercial citrus packing houses. Additon of phenate to the final wax emulsion coating promises to give longer protection. Investigations are continuing to determine the optimum concentration of phenate. Wastage due to *Phomopsis* stem end rot is important in longer storage. Excellent control of stem end rot was obtained by combining a dip in a solution of sodium salicylanilide with standard phenate treatment.

The foam method of waxing citrus fruits has been fully tested and is being used in commercial packing houses where it has considerably reduced waxing cost.

Improved methods of cleaning citrus fruits have been developed to meet increasing needs by individual growers and packing houses. Black spot is the most serious disease of New South Wales coastal Valencia oranges; its development on picked fruit has been greatly reduced by the phenate-wax coating under both experimental and commercial conditions.

(vii) *Queensland Fruit Fly (Co-operative Investigations with Entomological Branch, New South Wales Department of Agriculture)*.—Studies continued of post-harvest disinfestation of oranges by fumigation with ethylene dibromide (EDB). In 93 experiments since 1957 involving 77,583 larvae in artificially infested fruits uptake of EDB by fruit juice during fumigation with 1 lb. EDB /1,000 cu. ft. at 70° F. for 2 hr. was not less than 1.5 p.p.m. and no larvae survived. Odd survivals occurred in three experiments in which EDB uptake was less than 1.5 p.p.m. Investigations commenced of variability in uptake of EDB and of fumigation at lower temperatures to put the treatment on a satisfactory basis for commercial application.

9. CANNING AND FRUIT PRODUCTS.

(Division of Food Preservation and Transport.)

(*a*) *Vegetable Canning.*—Investigation continued of the quality of canned green peas. The redesigned maturometer, developed by the Division as a control instrument for harvesting and processing green peas, is now in commercial production. A motorized instrument incorporating a new sampler plate will shortly be available.

Investigation of the water blanching process has shown that its main function is elimination of gases from the peas prior to canning. This is effected by immersion for 30 sec. at 200° F. Reduction in time from the conventional three-minute treatment reduces undesirable leaching of soluble constituents and gives a sixfold increase in output of the blancher unit. Further work is in progress on alternative blanching techniques.

The mobile pea harvester is assuming economic importance as a substitute for the stationary viner, and studies have been made of relative efficiencies of these alternative methods. The mobile harvester gave about 80 per cent. recovery of peas from vines by comparison with the orthodox viner, and there was no significant difference in damage to peas by either method.

(*b*) *Fruit Canning.*—Although it has long been known that pears may turn pink when overcooked, this discoloration is not normally a defect in canned pears. However, spasmodic outbreaks of "pink pears" have occurred during recent seasons and, in response to requests from canners, an examination of this problem has been undertaken. At present, chemical and spectroscopic evidence suggests that the pink pigment is of the anthocyanin type, but complete indentification is difficult because it is present only in small amounts and is firmly held in the pear tissue. Pears are known to contain leucoanthocyanins, colourless compounds converted to anthocyanin pigments when heated in acid media, and this is probably the primary reaction causing pink discoloration during processing. Wide variability between pears in susceptibility to pink discoloration appears due to differences in leucoanthocyanin content. A preliminary survey of canning pears in the Goulburn Valley showed significant correlation between soluble solids content and leucoanthocyanin content. It is hoped to study more fully in another season the effects of field and storage factors on pear susceptibility to pink discoloration.

Berry canning investigations at Hobart have shown that syrup concentrations used at present in canned berries are generally satisfactory and that berries canned with syrups containing added pectin are less acceptable than berries canned without pectin. Various heat processes are being studied in relation to the quality of canned berries.

Treatments are being evaluated to improve the performance of wooden punnets, used for transporting fresh berries.

Preliminary work is in progress in Hobart on preservation of apples by dehydro-canning.

(*c*) *Chemistry of Processed Foods.*—The four anthocyanin pigments of blackcurrants are believed to be the 3-monoglucosides and 3-rhamnoglucosides of cyanidin and delphinidin. The only aspect requiring confirmation is identification of the second delphinidin pigment as a 3-bioside rather than a 3,5-diglycoside.

Onion picklers occasionally encounter a condition known as "yellow spot" or "yellow-rot" which renders their product unacceptable. The yellow spots have been identified as crystalline aggregates of the yellow flavonoid pigment, quercetin, apparently formed by enzymic hydrolysis of a water-soluble derivative naturally present in onions. Amounts of quercetin compounds in brown onion varieties are six-ten times as great as those in white varieties favoured for pickling.

(*d*) *Container Investigations.*—A major problem investigated was occurrence of hydrogen swells in canned pears within a year of canning. Normal canned pears have a shelf life of at least three years, during which time tin goes into solution and hydrogen is evolved from exposed iron, but both of these processes are very slow. In some canned pears, however, corrosion behaviour is abnormal. Detinning is unusually rapid and the tin coating does not appear to exert its normal protective effect on the exposed steel. Accelerated local attack occurs at regions of tin plate strain and is accompanied by rapid evolution of hydrogen. This abnormal behaviour is aggravated by low initial vacua but is also evidently associated with the specific composition of the pears. Investigations continue of this problem in co-operation with canners, canmakers, and tin plate manufacturers.

10. FROZEN FRUITS AND VEGETABLES.

(Division of Food Preservation and Transport.)

(*a*) *General.*—Investigations on frozen fruits and vegetables have been devoted mainly to defining types and varieties suitable for freezing and to assessing the influence of agronomic and processing factors on the quality of the frozen product. Most of the information needed on these aspects has now been obtained. Future work will be directed chiefly to the elucidation of chemical and biochemical changes responsible for quality deterioration in frozen foods.

Survey of the frozen fruit and vegetable industry has been undertaken to provide information on technical problems. This information will assist design of future research programmes.

(*b*) *Frozen Vegetables.*—Investigation continued of the influence on acceptability of frozen peas of the alcohol insoluble solids content, date of harvest, and size grade.

A brief study was completed on the value of brine grading peas for freezing. Consumers were found to prefer "floaters" from brine grading to ungraded peas, while "sinkers" were rated inferior to those ungraded.

Sweet corn, like peas, matures very rapidly and the period is restricted for harvesting at optimum quality. Moisture content and alcohol insoluble solids are reliable indices of maturity and have been used to determine the preferred maturity. Consumer acceptability tests indicate a preference for sweet corn of 67.5-72.0 per cent. moisture. The corresponding frozen product has a moisture content of 68.5-73.0 per cent. and an alcohol soluble solids value of 25-20 per cent. These data will be confirmed by study of further crops.

Frozen cauliflower often discolours during storage and the possibility is being explored that this may be associated with the blanching method or solar radiation of the curd before or after harvest.

Equipment has been designed and constructed to permit assessment of the oxygen influence on storage stability of frozen foods.

(*c*) *Frozen Fruit.*—An attempt to determine whether freestone peaches give a better frozen product if picked before ripening and later ripened off the tree was inconclusive owing to raw material variability.

The effects of storage temperature and vacuum syruping on raspberries and strawberries have been examined and data are being analysed.

Frozen berries often have certain flavour and texture defects after thawing. Investigations are in progress in Hobart to test remedial measures, such as application of heat, partial dehydration, vacuum syruping, and thickening agents.

11. DEHYDRATED FOODS.

(Division of Food Preservation and Transport.)

(*a*) *Vegetables.*—Intact skins of green peas hinder water removal during dehydration. In addition, they prevent complete reconstitution during cooking, resulting in a shrivelled appearance of part of the sample. Skin slitting before processing by mechanical means resulted in samples with faster drying rates and better reconstitution than untreated samples.

Quality tests continued on potato varieties recently developed by the New South Wales Department of Agriculture. Most samples were of high quality.

"Instant" dehydrated potato flakes, developed in America, are well established there and production is commencing in Europe. Assistance was given to concerns wishing to establish the process in Queensland.

The Karl Fischer method of water determination is being studied over a wide moisture range in foods. Rapid water determinations are necessary for dehydro-freezing and dehydro-canning where partial dehydration is followed by other processes.

Building commenced of a belt-trough dryer to provide more efficient partial dehydration associated with the combined preservation processes.

(*b*) *Fruit.*—Specifications for sulphur dioxide level in dried tree fruits are higher within Australia than in importing countries. Consequently, exporters have recently experienced difficulties. Tests commenced on methods for reducing sulphur dioxide levels in existing stocks.

Basic data accumulated on absorption and retention of sulphur dioxide by tree fruits have been applied to pilot-scale plant. Initial tests on this plant were satisfactory and further work should result in better methods being available for commercial control of the process.

Recommendations arising from tests on prune dehydrators at Young resulted in greatly increased drying efficiency.

Studies have been completed on the efficiency of typical apple-drying kilns in Tasmania. Hot air passing through the layer of apple slices is utilized with reasonable efficiency in evaporating moisture from the fruit. Methods of heating air below the drying floor may, however, be very inefficient from the point of view of fuel consumption.

An electrical moisture meter is under test for use in estimating the water contents of apples in Tasmania dehydration factories.

(*c*) *Dehydrated Mutton.*—Collection continued of physical data on drying rates of precooked minced mutton. Meat fat content influences rate of drying and requires careful control of commercial production. Examination of the data indicates that drying conditions may be varied widely without serious effect on quality and shelf life.

Oxidative changes in dried mutton, resulting from air in the packs, have been restricted by replacing the air with nitrogen. At least 98 per cent. of the oxygen must be removed to produce a satisfactory gas pack. Storage lives of four different types of pack have been compared; these were air pack, block pack, fat block pack, and nitrogen pack, in order of increasing shelf life.

Two investigations were carried out on restricting "browning changes"; the first was concerned with addition of sulphur dioxide to meat and the second with lowering of moisture content below 2 per cent. by including "in-can" desiccants. The presence of sulphur dioxide had pronounced stabilizing effects both in the presence and absence of air. Shelf life was enhanced slightly in air and nitrogen packs by lowering moisture content but effects were too small to warrant recommendation of the procedure for commercial practice.

(*d*) *Dehydrated Beef.*—Processing and storage studies have been carried out on air-dried minced beef. It has been shown that methods found suitable for mutton may be used equally well for beef.

Results of storage studies on New Zealand vacuum dried raw beef chunks have shown that the product reconstitutes very slowly and further work is required to improve storage life.

12. DAIRY RESEARCH.

(Dairy Research Section.)

(*a*) *Cheese.*—In work on mechanization of Cheddar cheese manufacture, commercial trials of the prototype automatic milling, salting, and hooping plant showed its suitability for factory use and provided data on which to base modifications to the commercial version. These included an improved salt apportioning device.

The curd fusing section of the equipment was redesigned to increase its capacity and to make it suitable for manufacture by the traditional method.

Arrangements were completed with James Bell Machinery Pty. Ltd. for commercial development of this machinery. Construction is almost complete of the first full-scale milling, salting, and hooping plant. After extensive trials with mock-up sections design of the commercial curd-fusing machine has reached the final drawing stage.

Studies continued on physico-chemical factors involved in shrinkage and dehydration of curd during cheesemaking.

In the bacteriology of cheese, problems examined included assessment of new cheese starter cultures, pairing of cultures to avoid destruction by heterologous bacteriophage, mechanism of gas production, and fluid separation in film-wrapped cheese.

Experiments were made on the manufacture of a Camembert-type cheese.

Large-scale experiments in the export of rindless, film-wrapped cheese resulted in improved wrapping techniques. Major benefits to the industry can be expected from this more attractive method of presentation of cheese.

A survey was completed of problems in cheese waxing.

(*b*) *Flavour Chemistry.*—Studies are complete on "fish-oil" flavour in butterfat and the mechanism and conditions necessary for production of this defect are now better understood. Compounds responsible for fishy flavour in dairy products made from washed cream have been identified and work commenced on flavour compounds in tallowy butterfat.

Gas chromatography has been the major tool in this work and its usefulness has been increased by improvements to the apparatus.

(*c*) *Microstructure of Dairy Products.*—Microscopical studies have been mainly concerned with the effect of different treatments on the physical form of casein in dairy products. Fluorescence and anoptral phase-contrast microscopy proved useful techniques. These studies confirmed results obtained by indirect methods that in liquid milk products casein exists as spherical particles or micelles of varying size; also certain physical and chemical treatments cause aggregation of the micelles. Treatment with rennet results in aggregation of micelles and later in partial fibre formation. In cheese-making further fibre formation takes place as a result of acid development and stretching or deformation in the cheddaring stage. A membraneous form of casein has been observed in foams from milk.

(*d*) *Milk Proteins.*—Understanding was gained of forces responsible for stabilization of the casein micelle from viscosity and turbidity studies on concentrated skimmed milk.

To assist manufacturers of caseinates the effect was studied of pH, temperature, and concentration on the viscosity of caseinate solutions.

A tracer technique was developed for following syneresis of rennet curd.

(*e*) *Butter.*—Experiments with cold-stored butter processing showed the extent to which surface deterioration of the bulk butter was responsible for loss of quality in the 1 lb. prints. Under laboratory conditions surface oxidation of cold-stored butter was not caused by drying of surface layers. Oxidation was in fact retarded by extreme desiccation at the surface and was encouraged by moisture uptake from storage in a moist atmosphere. Surface oxidation was directly related to the copper content of parchment wrappers.

(*f*) *Sodium Hypochlorite in Milk.*—A field survey was carried out in three States on the incidence in milk supplies of sodium hypochlorite, a common sterilant on dairy farms; 2,000 samples were examined. In fifteen supplies (0.7 per cent.) hypochlorite was detected at levels of 20 p.p.m. active chlorine or higher.

(*g*) *Casein.*—Adequate washing is an important factor in production of high quality casein. Analytical techniques for assessment of washing efficiency were therefore studied and washing requirements determined.

Commercial factory trials confirmed pilot-scale washing experiments. In collaboration with machinery manufacturers, a plant was designed for washing acid casein.

(*h*) *Miscellaneous.*—The thiobarbituric acid test, used as an index of fat oxidation, also gives a positive reaction with other compounds.

Investigations commenced to elucidate the mechanism involved. It was found that any compound capable of producing malonic dialdehyde directly or indirectly under the test conditions will give a positive reaction.

The effectiveness was studied of continuous dialysis in the manufacture of high-protein milks.

13. DRIED VINE FRUITS.

(Commonwealth Research Station, Merbein.)

Little difference in performance was found between commercial dipping oils available in 1959 for hastening sultana drying. No need was found to alter the customary rate of fruit spreading on drying racks after use of such modern oils.

Harvest conditions for grapes were excellent this year. Skin condition of grapes, assessed with a maturometer, remained good throughout. Virtually no mould problem arose; a trial with sorbic acid as a mouldicide spray was inconclusive.

A laboratory procedure for determination of sand residues in dried vine fruits was developed. This was used in a commercial trial of a fruit washing machine.

Rack dehydration of vine fruits was examined further under an arrangement between the Department of Primary Industry, the Commonwealth Dried Fruits Control Board, and the Australian Dried Fruits Association. An officer of the Chemical Research Laboratories continued investigations towards greater utilization of solar energy in fruit drying on racks.

Abnormal swelling of sultanas in fruit minces is being examined in association with the British Food Manufacturing Industries' Research Association.

Hollow seeds in raisins, which cause difficulties in deseeding, have been found in Waltham Cross grapes much more than in Gordos, formerly believed the main source of trouble.

XIV. FOREST PRODUCTS.

1. GENERAL.

Fundamental data on the properties, potentialities, and correct methods of treatment of Australian timbers are essential for the development of the nation's forest resources.

The Organization's Division of Forest Products, in Melbourne, was forced to carry out investigations on Australian forest products, and to provide direct assistance to all concerned in the use of timber.

The Division's research is directed toward more effective use of timber resources, by reducing waste in forest, mill, and factory; by reducing losses from decay and insect attack; and by improving for timber and pulp the quality of wood produced in the growing forest by the study of wood properties associated with tree breeding and silvicultural treatment.

The work of the Division of Forest Products is reported in this chapter. Work on timber pests is undertaken by the Division of Entomology (see Chapter IX., Section 14).

Division of Forest Products.—No major changes have been made in the research programmes of the Division during the year, nor have there been any changes in senior or administrative staff.

A Forests Products Research Conference was held in the Division in November, 1958, to correlate the programmes of the Division with those of the State Forest Services.

For some years the Division has been seriously hampered by lack of laboratory space. This is now being overcome with the acquisition of buildings adjoining the Division which increase the total ground area of the site by about 50 per cent.

Inquiries remained steady at 12,000 and visitors to the Division totalled over 3,000. Some 300 students and teachers were also shown over the Division in parties.

A new series of technological papers was commenced to disseminate more widely the results of investigations. The *Forests Products Newsletter* was continued as a monthly production with a wide circulation throughout industry.

Research programmes continued in co-operation with the Australian Plywood Board, the pulp and paper industry, the pole-using authorities, and the forest services. General contributions from the timber and allied industries have been maintained, totalling approximately £2,500 for the year.

The help and co-operation of the State Forest Services, the Commonwealth Forestry and Timber Bureau, the New Guinea Department of Forests, the paper companies, the Australian Plywood Board, the pole-using authorities, and all branches of the timber and allied industries are gratefully acknowledged.

2. WOOD AND FIBRE STRUCTURE.

(Division of Forest Products.)

(*a*) *Anatomical Investigations.* (i) *Bark.*—The barks of 82 species of *Eugenia* sens. lat. have been examined. The separation into *Eugenia* A and *Eugenia* B on the basis of wood anatomy has been upheld by features of bark anatomy, thus supporting the suggestion that the species of *Eugenia* from the Old World should be separated from those of the New World. Some unusual fibres have been described.

(ii) *Pit Structure.*—It has been shown by optical and electron microscopy that the membrane of the pits in *Eucalyptus regnans* retains the essential structure of the primary wall. In consequence it offers much greater resistance to the movement of particulate suspensions than the perforated membranes in coniferous woods. The pit borders in fibres and tracheids consist of a circular ring of microfibrils. However, in vessel elements, the initial deposition of the border is common to a number of pit fields. The structure of the peculiar thickenings around the tracheid pits of *Callitris glauca* has also been investigated by using techniques of ultraviolet and electron microscopy.

(*b*) *Identification and Identification Methods.*—Over 1,000 timber specimens have been identified for private individuals and the trade in Australia, and for the Forests Department and the Resources Survey team in New Guinea. Chromatographic examination of extractives from the woods of closely related species has been continued with the use of further samples of *Nothofagus* from New Guinea, New Zealand, and South America.

(*c*) *Microscopy of Semi-chemical and Mechanical Pulps.*—Because of the increasing importance of these pulps in the paper industry structural changes associated with their preparation have been investigated, by using "Masonite", "Asplund", cold soda, and groundwood pulps. In those processes involving high temperature, separation in the zone of the intercellular layer occurs. Thus, a predominantly lignified surface is exposed as the bonding surface. On the other hand, in the cold soda process the predominantly cellulosic surface of the middle layer of the secondary wall is exposed and constitutes the bonding surface. In mechanical pulp the separation occurs across the cell walls.

(*d*) *Lignification in Model Systems.*—Studies on the progress of natural lignification in woody plants have been extended to various model systems in order to assist in the understanding of the mechanisms involved. Control of degree of lignification might then be possible. To this end the system eugenol-peroxidase-hydrogen peroxide has been investigated by using *Avena* coleoptile parenchyma and stems of *Eucalyptus regnans* and *Pinus radiata* as experimental material. The eugenol "lignin" so produced is deposited between the microfibrils, thus stiffening the wall. The reaction is not influenced by the presence of some reducing substances. In woody stems the products of the reaction are different in the cambial zone from those in partially differentiated wood. The course of lignification appears to be controlled by the reducing potential of the cells in which the reaction takes place. Eugenol destroys the osmotic properties of the cells and so the reaction is confined to the cell walls and does not involve participation of the cytoplasm. The chemistry of the process has been followed by studying the ultraviolet absorption spectrum of the lignin-like material deposited in the coleoptiles. This is similar to that of natural lignin. The artificial "lignin" also behaved like natural lignin in the sulphuric acid determination. As no lignin was formed when eugenol was replaced by coniferin glycosidase was not present in the coleoptiles. Further work is in hand to establish the relationship between this artificial lignification and natural lignification.

(*e*) *The Nature of the Warts in Conifer Tracheids.*—These are excrescences on the cell wall the significance of which is unknown, but they are considered to play a part in governing the penetration of liquids into wood. Their structure has been investigated in a variety of gymnosperms and methods devised by which they can be isolated. They consist of a membrane folded into a series of pouches protruding into the cell lumen. In these are spherical objects which appear to be extremely dense. Development of the warts occurs late in the differentiation of the cell wall following lignification. Chemically they are extremely consistent and their solubility properties resemble those of sporopollen.

(*f*) *Surface Growth in Plant Cells and Formation of the Secondary Wall.*—The study of surface growth in differentiating fibres and tracheids has been continued using the techniques of autoradiography and electron microscopy. The synthesis of cellulose is uniform over the cell surface. This is consistent with evidence that the multi-net mechanism of growth is operative in these cells. From autoradiographic and interference microscope studies the secondary wall formation has been shown to commence near the centre of the cell and proceed towards the cell tip.

(*g*) *Wood and Bark Extractives.*—Extracts from tissues of different eucalypt species and the kinos of these species have been examined and several components identified. A new staining technique was developed for leucoanthocyanins in xylem tissues.

Problems encountered in the handling of black liquor from the pulping of eucalypts were shown to be associated with the presence of ellagic acid and its derivatives.

To assist the assessment of commercial polyphenols as a basis for wood adhesives, the reaction was studied under different conditions between a model compound (catechin) and formaldehyde. Less reaction occurred at pH 4.5 than at other pH values between 1 and 10, and the reaction was confined to the phloroglucinol ring of catechin. The reactivity of commercial polyphenols was also at a minimum at pH 4.5, and they combined with most formaldehyde at pH 8, although the amount differed with different polyphenols.

3. WOOD CHEMISTRY.

(Division of Forest Products.)

(*a*) *Methanol Lignin from* Eucalyptus regnans.—The examination of methanol lignin which had been freed from lignin monomers and degraded lignin by counter-current distribution has been completed. It was demonstrated chromatographically that the lignin so obtained was not a single substance. The methoxyl content corresponded to 1.86 groups per phenylpropane unit of which 0.41 were removed by acid treatment. This corresponds to a ratio of syringyl to guaiacyl units of 1:1 and spectroscopic data on ultra-violet absorption were in accordance with this. However, oxidation gave syringaldehyde and vanillin in the ratio of 4:1; this indicates that three out of four guaiacyl units were carbon linked. It contained 0.35 phenolic and 1.05 aliphatic hydroxyl groups per phenylpropane unit and the presence of carbonyl was shown by its infra-red absorption spectrum. All results obtained showed the eucalypt lignin to have an essentially similar structure to spruce lignin except that half of the guaiacyl units are replaced by syringyl units.

(*b*) *Carbohydrate Investigations.* — Glucuronic and xyluronic acids and several *O*-methyl derivatives of these acids are being prepared. The yields of furfural and of carbon dioxide from these acids will be obtained as an aid to the interpretation of the results of proximate analyses of cellulosic materials, for uronic acids and pentosans.

Preliminary work has commenced on the structure of the non-resistant and resistant non-cellulosic polysaccharides of *E. regnans*.

Saccharinic acids are being prepared for use in studies concerned with the alkaline degradation of cellulose.

(*c*) *Thermal Degradation of Cellulose.*—Treatments have been carried out in the presence of air, oxygen, nitrogen, and under vacuum, and at different rates of gas flow at temperatures up to 400° C. Residues and tars from these treatments were examined by infra-red spectroscopy, and laevoglucosan could be readily detected. Treatment of the products of oxidation and pyrolysis by sodium hydroxide and sodium borohydride permitted a clear distinction to be made between their carboxyl and carbonyl contents. The influence was studied of metal salts on the rate of thermal degradation. Samples of eucalypt cellulose were treated with ferric chloride solutions of various concentrations and degradation rate curves constructed from the variation with time of heating of the intensity of various infra-red absorption bands.

(*d*) *Correlation of Constituents with Papermaking Properties.*—Pulps with lignin contents ranging from 2 to 22 per cent. were obtained from a cold soda *E. regnans* pulp by treatment with sodium chlorite for various periods. All resulting pulps had similar pentosan contents. All pulp strength properties increased with decrease in lignin content.

(*e*) *Influence of Fibre Properties on Pulp Strength.*—The influence of fibre length has been studied by cutting *Araucaria klinkii* chips, delignified by sodium chlorite treatment, into short lengths. The average fibre length of this sample was over 8 mm. The pieces were defibred by treatment with dilute alkali followed by gentle mechanical agitation. By this procedure a series of "pulps" was obtained, identical in all respects except for fibre length. Tearing strength showed a linear increase with fibre length with the unbeaten "pulps". Fibre length appears of importance for tearing strength but not so important for strength properties depending mainly on fibre bonding. Investigations using conventional pulping processes on material with fibres of different lengths (real and artificial) have shown similar trends.

(*f*) *Flow of Pulp Suspensions in Relation to Beating and Stock Pumping.*—To eliminate the effects of flocculation and sedimentation on the flow properties, observations were made with fibres dispersed in a sugar solution of high viscosity. The use of intact fibres of *Eucalyptus*, *Pinus*, and *Araucaria* indicated the influence of fibre length on the effective viscosity, but quantitative interpretation was obscured by the distribution of fibre lengths within each pulp type and by the differing wall thickness and flexibility of the various fibres. However, fractions of rigid fibres of uniform length and cross section were obtained by cutting delignified long-fibred klinki pine veneer into strips equivalent to the fibre length required, followed by alkali treatment and careful disintegration. From observations on suspensions in the range of fibre length up to 4 mm. and of concentration up to 1 per cent. the conditions were determined under which non-Newtonian flow becomes significant.

(*g*) *Drainage Resistance of Pulp.*—Measurements have been made of the characteristics of 32 pulps by means of an apparatus built for automatically recording drainage rate data. The simplest application of these data is in computing drainage resistance from reasonable assumptions in respect to pressure losses within the apparatus, the compressibility of the fibre pad during the filtration, or papermaking operation and the effects of sedimentation. Each of these assumptions has been reviewed. A modification to the theory was developed to allow for kinetic hydrodynamic losses and their influence on the effective filtration pressure. The compressibility of the pad could lead to a dependence of drainage resistance on applied pressure, and arrangements were therefore made to measure the rate of continuous filtration.

(*h*) *Differences Between Pulps.*—The direct effect of the cooking liquor on the cellulosic material in the fibre might be of major importance in considering the observed differences. Cotton wool, cut to a length suitable for papermaking, was cooked with various sulphate liquors at 140 and 160° C. The beating rate of the cooked material, evaluated in terms of strength development, was considerably greater than that of the untreated sample, although the ultimate strength did not alter appreciably. When the cotton fibres were cooked in acidified sodium sulphite at 140° C. the resulting pulp was extremely weak, but treatment with sodium metabisulphite had little effect. The work was extended to include a virtually lignin-free wood pulp containing about 10 per cent. alkali-soluble polysaccharides.

(*i*) *Dimensional Stability of Paper.*—Recent applications of heat and cross-linking treatments to papers having a high eucalypt furnish have confirmed that: (i) Dimensional stabilization by such treatments is independent of the nature of the paper furnish; (ii) acidic salts can serve effectively as catalysts for cross-linking with formaldehyde; and (iii) embrittlement of paper is an inescapable artefact of dimensional stabilization and becomes serious above 40 per cent. On a paper made without size or filler, pretreatments which render paper relatively ash-free and thereby lower its pH are favorable to dimensional stabilization by heat treatment without added catalyst, but embrittlement is again a significant factor.

4. TIMBER PHYSICS.

(Division of Forest Products.)

(*a*) *Sorption Studies.*—The rate of approach to sorption equilibrium between water vapour and small samples of wood and related material has been investigated, and it has been observed to be dependent on both the initial and final vapour pressures for the step. The rate for large increments is faster than for small increments to the same final vapour pressure. Also, for a given size of increment the rate is faster at low than at high relative vapour pressures. The mechanism is thought to involve relaxation during sorption of stresses produced by swelling.

Chemical changes associated with delignification and pulping increased the sorption rate by up to twenty times, particularly at high humidities, but physical changes such as beating and paper sheet formation had little effect. The physical separation of the wood fibres during pulping does not appear to be the reason for the increased rate, since sections of wood less than one fibre thick do not equilibrate faster than wood samples 1-2 mm. thick.

With normal hardwood, tension wood, normal softwood, and compression wood the rates of sorption were not very different at low humidities, but at high humidities the rates for tension wood and compression wood were respectively faster and slower than for normal wood, differing from each other by a factor of 6.

It appears that the lignin content of the material is an important factor, lower lignin contents being associated with faster sorption of water vapour.

(*b*) *Rheological Studies.*—Tests to detect directly departure from linearity in the relationship between creep rate and applied stress below the discontinuity which occurs at about 67 per cent. of ultimate strength confirmed that the relationship is very closely linear. *Eucalyptus pilularis* proved generally similar in creep behaviour o *E. regnans* over the full range of stress from zero to ailure. A study of activation energy of the process shows o change at the point of discontinuity. The discontinuity s presumably an entropic phenomenon involving molecular chain strengthening in the amorphous region at and bove this stress. The flowing units are of the order of ize of the glucose residue.

Moisture increase and decrease whilst under load both cause increase in creep rate, and loss of moisture during stress relaxation increases the rate of relaxation markedly. In beams, the effect of such changes during creep was greater near the compression face than near the tension face.

In two years, beams of *E. regnans* have crept twice as much at 45° C. as at 20° C. In addition, at the higher temperature most of the creep took place in the first year, whereas at the lower the creep rate was still quite appreciable after two years.

An automatic machine has been built and the study commenced of the effect of temperature on creep at high stresses to determine the effect of temperature on the position and nature of the creep discontinuity.

A study of stress relaxation in wooden beams has shown the same pattern as for creep but at high stresses the relaxation is considerably less than the creep, even when this has been reduced by subtracting an amount based on Newtonian flow for irreversible deformation.

(*c*) *Electrical Moisture Meters.*—Correction figures have been obtained on seven additional species and, using a pressure-cell type of electrode, on a fibre for the manufacture of hardboard.

A study of the effects on moisture meter readings of ring age, height in tree, tree age, and locality of growth carried out on South Australian *Pinus radiata* showed no significant effect which could be attributed to ring age. However, an effect due to both locality of growth and height in tree is apparent.

Tests were carried out to determine the relative suitability of several methods for the determination of the moisture content of both treated and untreated veneer.

5. TIMBER MECHANICS.

(Division of Forest Products.)

(*a*) *Species Testing.*—The mechanical testing of green material of marri has been completed and tests are proceeding on green wandoo. Immature karri was much lighter, weaker, and less stiff than mature karri, whereas the immature jarrah had similar properties to mature timber. Tests are in progress on dry material of several species from the eastern States and on ten Fijian timbers in the green condition.

(*b*) *Silvicultural Tests.*—The very high correlation between compression strength and density was confirmed in tests on eight trees of radiata pine. The average within-tree correlation coefficient was 0.90 with one tree showing a coefficient as high as 0.98.

(*c*) *Timber Engineering.* (i) *Structural Design.*—The publication of the Timber Engineering Design Handbook has stimulated considerable interest in timber structures. This has resulted in many requests for assistance in timber design work, and requests for extension lectures on this subject. In an expanded programme, many structures have been designed including trusses, roof beams, columns, floor beams, joists, and self-supporting floor panels. The majority of these have been constructed and proof-tested.

Further tests have been made on composite concrete and timber beams, the timber being in the form of 10-in. diameter air-dried logs of mountain ash. Severe checking in the logs before the concrete was poured did not affect the final failure of the composite beams which generally failed by crushing in the concrete.

(ii) *Nails.*—All of the planned tests of nailed joints in radiata pine and yellow stringybark have been completed, and long-time loading tests commenced on joints in messmate stringybark. Tests have been completed on the variation in static holding power over a period of six months, of plain and cement-coated nails in timber kept green, partly seasoned, and dry. The load-withdrawal relationship for nails is being studied under static and impact loads.

(iii) *Glue.*—Shear tests have been made on glued timber joints to study the effect of varying the angle of applied load to the grain direction in the specimen, and also to find the effect on shear strength of the angle between the grain directions in the two pieces making up the joint.

(iv) *Columns.*—A further eight model columns were erected for testing. Six columns failed; three of these had sustained their test loads for two and a half years or longer; the other three held their loads for only two to three weeks. The latter were erected green and allowed to dry out during the test period, and each carried a load only 50 per cent. of its short-time failing load.

(v) *Scantling.*—The effects of gum veins and pockets on the strength and stiffness of jarrah scantlings have been investigated. Both defects significantly reduced strength and stiffness, the gum veins having an effect substantially greater than has hitherto been assumed. Distortion has been studied on drying of radiata pine scantlings. Twist, bow, and spring are at a maximum in wood near the pith.

Further mechanical testing and analyses of results have been made on 4 by 2 in. and 3 by 2 in. radiata pine scantlings to check the efficacy of the interim grading rules recently issued for this material.

(vi) *Poles.*—With the exception of radiata pine the testing has been completed of green poles of the several species studied. Recently pole testing has been confined largely to dried and de-sapped poles with their butts re-wetted to simulate service conditions. The strength of such poles appears to be somewhat less than equivalent green poles. The supplementary part of the pole-testing programme, involving the effect of preservative treatments on strength, has been continued. The effect has been studied of Boultonizing treatment on the strength of radiata pine, and also of creosote or a water-borne copper-chrome-arsenic salt on the five-pole species used in the programme. The Boultonizing treatment produces an immediate increase in strength, particularly in the less dense species.

(vii) *Plywood.*—A parcel of plywood representative of material that could be used for structural purposes was supplied by the Australian Plywood Board. Eighty of these sheets have been tested to compare their stiffnesses as beams and plates, limiting spans for the various species, and thicknesses for use of the plywood as flooring, roof sheathing, and concrete formwork.

6. TIMBER PRESERVATION.

(Division of Forest Products.)

(*a*) *General.*—A record number of requests for technical assistance in many aspects of wood preservation has been received during the year. Much time has been given to problems associated with the establishment and development of the pressure treatment industry in Australia. Special attention has also been given to demonstration and to dissemination of information on methods for treating fence posts.

(*b*) *Field Tests.*—Inspection of existing tests and the treatment of new material have continued. Pole tests at six localities in New South Wales and Victoria were inspected in the presence of more than 150 pole engineers and other technical personnel. Other tests inspected and demonstrated have included high-pressure treated rail sleepers in Tasmania, surface-coated sleepers in Victoria, and various treatments of round fence posts in two States.

New test material has comprised 100 treated radiata pine sleepers for extension of existing tests in Victoria; 584 sleepers for tests of various timbers and preservatives, now ready for installation in New South Wales; and 480 sleepers for treatment and installation in Queensland during the coming year. More than 1,000 small specimens for stake tests in various localities, including New Guinea, have been treated.

(*c*) *New Preservatives.*—A new project has commenced to assess the preservative value of distillate oils from brown coal tar produced by the Lurgi gasification process in Victoria, and from wood tar produced by the charcoal-iron plant in Western Australia. The wash oil at present produced at the Lurgi plant is a promising preservative being high in phenols and aromatic compounds, but is more volatile than bituminous coal tar creosotes used for wood preservation in Australia. Oils of higher boiling range are being tested.

Attention has also been given to the problem of formulating a leach-resistant metal-borate preservative and to the reformulation of the Division's borofluoride-chrome-arsenic preservative to permit use of arsenic pentoxide instead of sodium arsenate.

(*d*) *Diffusion Treatments.*—Satisfactory results have been obtained in laboratory decay and termite tests of the arsenical and non-arsenical borofluoride preservatives for use in dip-diffusion or pressure-diffusion treatment of green building timber. In these tests treated timber was leached by exposure for six months to over 14 in. of rain to simulate slow erection of a building frame. Field tests to simulate conditions in a building have been installed in an area where both *Coptotermes acinaciformis* and *C. frenchi* are common.

(*e*) *Factors Responsible for Durability of Heartwood.*—There is no great difference in the radial variation in decay resistance of plantation and naturally grown teak, except that the higher growth rate of plantation material usually results in a larger core of relatively non-durable wood. Such differences as do occur indicate that higher growth rates cause a slight reduction in decay resistance.

Tests on twelve durable and moderately durable eucalypts have shown that toxic extractives are responsible for durability with a minor effect of structure in some cases. Chromatographic separation of extractives from teak and eucalypts is proceeding, but the toxic compounds have not yet been fully identified. Work is now extending to a study of toxic extractives in Australian softwood timbers.

(*f*) *Mycology.*—Work has continued on the tolerance of wood-destroying fungi to inorganic preservatives. One strain of *Poria vaillantii* has been grown on nutrient agar containing 24 per cent. (w/v) $CuSO_4.5H_2O$ and has readily decayed pine blocks containing 10 per cent. copper sulphate or 6 per cent. copper formate (w/w basis); while blocks containing 12 per cent. (about 4 lb./c. ft. dry salt) of a proprietary copper-chrome-arsenic preservative were not fully protected.

Species of *Chaetomium, Emerellicellopsis, Fusarium, Gliocladium, Phaeoscopulariopsis, Pullularia,* and *Stemphylium,* isolated from cooling towers, have been used in an attempt to produce soft rot under laboratory conditions. Eighty small test trays, each containing one slat of each of 24 timbers, have been prepared for installation in selected towers and will be returned to the laboratory each year for observation on fungal infection and reduction in strength of slats.

7. Timber Seasoning.

(Division of Forest Products.)

(*a*) *Collapse and Recovery.*—Applied surface tension and vapour pressure changes were investigated in the capillary system of green wood as factors in collapse. Treatment with lithium chloride, calcium chloride, and manganese chloride reduced gross shrinkage in alpine ash heartwood to less than half.

The effect of steaming mountain ash whilst green was controlled by limiting the saturation temperature to 150° F. Shrinkage in alpine ash sapwood from mature and immature trees was reduced from 10 to 5½ per cent. by a soak treatment in 9 per cent. sodium chloride before drying.

A preliminary freeze treatment at —110° F. reduced collapse in mountain ash by some 50 per cent. Boiling as a reconditioning treatment was not as effective as steaming.

(*b*) *Drying Studies.*—Sawn messmate stringybark from 25-30 year old trees developed less degrade than similar aged mountain ash or silvertop ash. Warp in radiata pine framing timbers was reduced by drying in multiple widths; drying in a multiple thickness proved unsatisfactory; soak treatments with a polyethylene glycol for periods up to seven days proved ineffective in dimensionally stabilizing during drying sawn timber containing the pith.

The value was confirmed of presteaming for difficult ash eucalypt timbers; for 1-in. thick alpine ash a 2-4 hr. treatment reduced kiln drying time from green to fibre saturation point by three days. The drying behaviour of alpine ash and satinbox was greatly improved by two-four day soak treatments in a buffered saturated sodium chloride solution.

Incising increased the kiln drying rate of the outer 1 in. of sleepers of three eucalypts by some 50 per cent., but over the moisture content range 90-40 per cent. it did not reduce the type or intensity of drying degrade. Messmate stringybark, mountain ash, and silvertop ash sleepers air dried considerably better than those of peppermint or white stringybark. Air drying reduced the moisture content of the outer ½ in. from 90 to 43 per cent. in four months.

(*c*) *Equilibrium Moisture Content.*—A study to relate e.m.c. to weather conditions indicated that critical factors for sheltered outdoor exposure are temperature and relative humidity. Vapour pressure, wet bulb depression, wind travel, and rainfall showed no correlation. Under indoor conditions the summer-to-winter mean e.m.c. variation in the Melbourne metropolitan area was approximately 2 per cent. for pored timbers and 3 per cent. for non-pored species; extreme ranges were approximately twice these. An empirical equation was developed to fit e.m.c. data from short-term temperature and humidity cycles.

E.m.c. values for wharf timbers and piles above water level showed little seasonal variation from 25 per cent. For house timbers a consistent difference of 4-5 per cent. was recorded for the moisture contents of floor bearers and rafters.

(*d*) *Kiln Design, Equipment, and Industry Assistance.*—Predrier performance was examined, deficiencies analysed, and recommendations for improvement prepared. Performance tests were carried out on flue-gas heated kilns, and a number of units of low efficiency which were causing serious losses in the industry; design data and recommendations for improvement were prepared.

A combined kiln and reconditioning chamber of special design was developed, and drawings were prepared to convert a charcoal-wood drier to timber kilns. Work was continued on kiln protection. The most effective of preparations tested were an acid-proof ceramic cement with sodium silicate, and an epicote resin cement.

Designs for kilns, reconditioners, and other driers were prepared for 38 firms or research establishments in Australia, Papua, New Zealand, the United Kingdom, India, Singapore, and the Philippines, together with 42 designs for McCashney sawdust burning units.

8. PLYWOOD INVESTIGATIONS.

(Division of Forest Products.)

(*a*) *General.*—Plants were visited and field tests carried out in all mainland States, and lectures were given in Queensland and New South Wales as part of the co-operative research programme with the Australian plywood industry. A definite improvement has been evident in plywood quality compared with that before the co-operative scheme.

(*b*) *Veneer Cutting.*—Species work was continued using a number of Australian, New Guinea, and south-east Asian woods.

A multi-section knife technique gave close matching and permitted better investigation of pooling factors with limited material. Micro-bevel studies included commercial trials and laboratory investigations. These failed to give marked improvement on Vanikoro kauri, but a micro-bevel of 0.008 in. gave a definite reduction in transverse tensile strength with sempilor. Deeper hollow grinding proved of benefit in commercial trials where very sharp cutting edges were required.

Factors responsible for the delay in obtaining uniform peeling thickness of veneer following application of nose-bar pressure were investigated on the laboratory lathe. A number of low density species with high moisture contents tended to give surface tearing when peeled at normal nosebar settings. The damage which may be caused by hydraulic pressures could be alleviated only by reducing nosebar pressures and increasing peeling temperatures. The Indian ink technique of staining peeler checks for evaluation was improved by using vacuum techniques and sections of specific thickness.

Field work included a comparison of lathe and slicer settings. The industry generally has now adopted nosebar gauges for lathes and slicers. Measuring stations are being installed in many plants.

(*c*) *Veneer Drying.*—A laboratory veneer drier is being installed. In field investigations high wet-bulb temperatures have been found responsible for staining of sensitive species in mesh belt driers. Schedule work was carried out on several commercial driers to improve performance.

(*d*) *Gluing Research.* (i) *Tannin Formaldehyde.*—The effects of pH on gelation times, curing rates, and bond quality were examined. pH's of approximately 7 gave best results with mimosa tannins. Additions of urea gave worse results than controls at pH values of 3.5, 6.9, and 7.1 in both dry and wet tests. Gelation rates of tannin adhesive formulations were found to be affected by a number of additives. At 90° C. and pH 5 one additive produced gelation in less than one-fifth of the time of controls. Reaction rates were lowest at pH 3, although with one additive minimum reactivity was at pH 5.5. In one case the additive reduced the formaldehyde requirement for gelation to 60 per cent. of normal. Laboratory formulations of phenol formaldehyde fortifiers showed similar gelation-time sensitivity, in some instances times being reduced from quarter to half that of controls.

(ii) *Phenol Formaldehyde.*—Small additions of borax gave reduction in gelation times while large additions produced an increase.

(iii) *Glue Line Preservatives.*—Following successful termite laboratory tests carried out by the Division of Entomology on arsenious oxide in plywood glue lines, the effects of various glue line preservatives on adhesion were examined. Arsenious oxide and chlordane behaved satisfactorily, but on karri, dieldrin gave significant reductions in strength at high concentrations. A liquid phenolic formulation tolerated moderate loadings of mono-ammonium phosphate applied by instantaneous diffusion-dip methods.

(iv) *Urea Formaldehyde.*—To high-protein wheat flour extenders, 1 per cent. sodium sulphite was added to give a suitable viscosity. Additions of arsenic trioxide up to 5 per cent. had little effect on dry and wet strength of urea formaldehyde bonds but showed slight reductions in dry and wet tests with resorcinol formaldehyde.

(*e*) *Exposure Tests.*—Weatherometer exposure tests on two species using phenolic resins on borax treated and control material favoured controls but show little difference after one year's weather exposure.

(*f*) *Veneer Flattening.*—Permanent deformation in veneers strained along the grain at 120° F. has been found to develop much more rapidly during desorbing conditions from 17 to 7 per cent. moisture content than in veneers strained at constant moisture content within this range. Increasing residual deformation corresponds very closely to moisture losses in two species tested. Similar indications have been obtained with transverse strains and the results concern bending, flattening, buckling, and set in veneers.

(*g*) *Plywood Buckling.*—Longitudinal shrinkage variations of 0.1-0.4 per cent. green to dry have been observed in commercial veneers and have been shown to produce distortion in cold and hot pressing. Relief of stresses in the buckled sheets has been obtained by desorption treatments or cycling at appropriate temperatures, particularly where distortion is due to internal tensions with peripheral compression.

(*h*) *Glue Spreading.*—Laboratory studies on glue spread control using formaldehyde formulations have established that doctor roll tolerances are low. Very small movements between doctor and spreader roll cause considerable variation in the spread rate. Viscosity and spreader roll clearances appeared to be of secondary importance within the limits of these experiments.

9. UTILIZATION.

(Division of Forest Products.)

(*a*) *Timber Uses.*—Information was supplied on the suitability of timbers for 200 uses, and advice given on the properties and uses of 160 species.

(*b*) *Manufacturing Processes.*—Sawmillers and associated manufacturers continued to seek the advice of the Division, and assistance was given in the design and layout of twelve new sawmills and ten existing sawmills undergoing improvement. Plans for a case plant and two distributors' yards were prepared. Attention previously directed towards the advantages of headsawing instead of breaking-down led during the year to re-organization of practice and installation of modern carriages in several sawmills.

(*c*) *Sawing.*—In the ash group of eucalypts speed tests approximating 10,000, 8,500, and 7,000 ft./min. have indicated that the intermediate speed is the best from the point of view of power consumption, saw durability, and saw stability. The slowest speed was previously shown to give advantages in the harder species.

Study on the use of thin saws in the ash group of eucalypts demonstrated that reductions of two to three gauges are practicable if slower rim speeds are used.

Continued assistance was given in planning and integrating sawmill studies on the power consumed in sawing hardwoods under various conditions.

Studies on tooth profiling were continued and lateral deflections of the saw blade and teeth were shown to have considerable influence on lacquer wear on the tooth tops. When tooth deflections were minimized a critical clearance of ½° for sharp teeth was recorded, agreeing fairly closely with pendulum dynamometer results.

Field tests of chain saws of recently improved designs established their ease of operation and faster sawing, and this has stimulated industry to arrange the import of a range of models for trial under industrial conditions.

(*d*) *Waste Utilization.*—Study of finger-jointing as a means of utilizing unpopular or discarded short lengths led to the installation of three commercial plants, for two of which the Division prepared layout plans. Simple bending tests on experimentally finger-jointed material from seven species ranging in density from 32 to 67 lb./cu. ft. revealed that average joint bending strengths up to 70 per cent. that of matched unjointed timber are obtainable.

The bending strengths of vertical- and horizontal-type joints have been compared and the vertical-type joint found to be slightly the stronger. Investigations into the effect on joint strength of varying end pressures during assembly are proceeding.

Flooring panels of both commercially and experimentally produced finger-jointed boards have been tested and found to conform to the requirements of the Commonwealth Experimental Building Station's standard flooring test.

XV. BUILDING.

1. General.

Building has such wide ramifications and uses, and such a diversity of products that research in Australia on problems relating to building and construction is spread throughout a number of establishments. At the Commonwealth Government level three of these—the Organization's Division of Building Research, the Commonwealth Experimental Building Station, and the Building Research Liaison Service of the Department of Works—are engaged solely on building research or the dissemination of its results. The Organization's Division of Forest Products, Chemical Research Laboratories, and Soil Mechanics Section, the Defence Standards Laboratories of the Department of Supply, and the Industrial Services Division of the Department of Labour and National Service, deal with those aspects of building research that come within their respective fields.

The work of the Division of Building Research is described in this Chapter. The work of the Division of Forest Products is described in Chapter XIV. Research by the Soil Mechanics Section is described in Chapter II., Section 8. Work on cement and ceramics by the Chemical Research Laboratories is described in Chapter XVII., Section 3.

Division of Building Research.—The Division has now been admitted to full membership of the International Council for Building Research, Studies, and Documentation, whose main purpose is to encourage, facilitate, and develop international co-operation in building research and the distribution of literature on building.

The Division's laboratories were opened for inspection for two days and evenings in March. Over 2,000 visitors attended, most of whom were associated directly or indirectly with the building industry. It is proposed to hold further Open Days at appropriate intervals.

The Division assisted the Antarctic Division of the Department of External Affairs by making its special facilities available to Dr. G. M. Budd for physiological studies at low temperatures. Officers of the Division delivered extension lectures at the University of Sydney and the Royal Melbourne Technical College. Lectures were also given to students of architecture at the University of Melbourne.

2. Architectural Acoustics.

(Division of Building Research.)

The Division took a leading part in the design of the sound reinforcement system used in Melbourne's recently completed Sidney Myer Music Bowl which has been awarded the Reynolds Memorial Architectural Award by the American Institute of Architects. This Bowl is an out-door auditorium with a large canopy covering the stage and about 2,000 of the audience in fixed seating. Another 25,000 persons can be seated on grassed areas within sight of the stage. A combination of several loudspeaker units was necessary to provide good listening conditions for both speech and music for so many people assembled over a very large area. After a careful theoretical and experimental investigation recommendations were made for the provision of two columns of loud speakers near the stage for the audience under the canopy and three columns of loud speakers (curved from top to bottom to give included angles of 5-10°) near the main supporting cable of the structure for the audience outside the canopy.

For structural and economic reasons lightweight construction is playing an increasing part in modern building practice. Unfortunately, this trend conflicts in principle with an important acoustical property of a structure—its sound insulation. It has therefore become necessary to direct attention to sound transmission studies. Methods for measuring the transmission loss of partitions are being studied. Understanding of all factors that have a bearing on the propagation of sound waves in porous materials will assist studies into sound transmission through lightweight materials and into sound absorption by acoustical materials. However, although basic knowledge available on wave propagation in rigid or flexible porous materials is far from satisfactory, the experimental technique developed in the Division for measuring the reflection and transmission characteristics of discontinuities in ducts can be applied to the propagation parameters of wave motion in layers of porous materials.

3. Bituminous Materials.

(Division of Building Research.)

Following a survey of flat roof construction throughout Australia several years ago, work on bituminous membranes has continued. Laboratory examinations and field trials have been made on experimental membranes and their performance observed at intervals over long periods. Analysis of these data has yielded only a few statistically significant conclusions, mainly because the number of variables is too large in relation to the number of experimental roofs. Nevertheless, a large amount of valuable information has been obtained.

(*a*) *Roof Membrane Maintenance.*—Study of surface treatments to prevent weathering of roofing felts has shown that bituminous films applied as clay-stabilized bituminous emulsions resist weather more satisfactorily than bituminous films applied hot. The most promising treatment is reinforcement of the emulsion with glass fibre tissue to prevent cracking, and finishing with a bituminous-based aluminium paint to reduce erosion.

(*b*) *Coal Tar Pitch Membranes.*—The performance characteristics of coal tar pitches and residual bitumens are being examined by laying two experimental membranes on a roof sloping 1 in 45. Coal tar pitch and residual bitumen are easier to lay than the blown bitumen usually used for roof membrane, but they tend to crack at low temperatures and flow at high temperatures. However, cracks that do form are more or less self-healing as the temperature rises.

(*c*) *Addition of Fillers to Bituminous Coatings on Roofing Felts.*—Bituminous coatings incorporating inorganic powders and exposed at a considerable angle to the horizontal are more durable than unfilled coatings. Since filled coatings absorb more water than unfilled coatings their advantage may not be so great for nearly horizontal exposure. Information on this and on filled coatings in general is being obtained with a series of experimental coatings employing various fillers and bitumens.

(*d*) *Fungal Growth on Roofing Felts.*—Fungal growth on roofing felts is being studied in relation to the deterioration of bituminous membranes. All types of conventional roofing fabrics available commercially support fungal growth, the susceptibility decreasing in the order: organic fibre (rag), organic fibre (paper), hessian, asbestos fibre, and glass fibre. Immersion of the materials in a 1 per cent. solution of sodium pentachlorphenate prevented fungal growth. Bitumen films alone did not support any fungi.

4. CLAYS AND CLAY PRODUCTS.

(Division of Building Research.)

(*a*) *Regional Studies of Australian Clays.*—Clays are being studied from Melbourne and adjacent areas in Victoria and from the Permian deposits of New South Wales, the latter in collaboration with the New South Wales Department of Mines and the Geology and Geophysics Department of the University of Sydney.

(*b*) *Moisture Expansion of Clay Products.*—Because of the importance to the building industry of the problems arising from the expansion of clay products on exposure to moisture, a study of the expansion of all such products made in Australia was started five years ago. All clay products so far examined expand once they leave the kiln and are exposed to the action of water, whether it be steam at high temperatures, liquid water at ordinary temperatures, or atmospheric water vapour. The rate and extent of the expansion can be independent of the physical state of the water (i.e., liquid or vapour) and of the concentration of the water in the air. Recommendations have been made to prevent damage to brickwork through expansion and the associated restraint imposed by the use of strong cement mortars or the lack of adequate expansion joints or both.

(*c*) *Durability of Clay Roofing Tiles.*—Study has continued of the deterioration of clay roofing tiles along the Australian coast. This was originally undertaken at the request of the Roofing Tile Manufacturers' Association of Victoria, but was later extended in co-operation with the Australian Clay Products Association Ltd. to cover the whole of Australia.

The most important process in tile deterioration is the crystallizing action of common salt in the overlapped and underneath parts of a tile. The salt is derived from sea spray near the coast and from the body of the tile. Light-burnt tiles are less durable than well-burnt ones. Salt glaze does not protect a tile since salts, crystallizing between the body of the tile and the glaze, strip the glaze and damage the body of the tile.

(*d*) *Industrial Potentialities of Clay Materials.*—Pilot-plant tests are still the only reliable method of assessing the industrial potentialities of clays. However, such tests are time-consuming, and studies are therefore being made concurrently of the mineralogical constitution, differential thermal behaviour, and particle size distribution of the clays to find out if correlations between practical behaviour and basic properties are possible.

5. CONCRETE INVESTIGATIONS.

(Division of Building Research.)

Research on concrete has been directed towards reducing its weight without seriously reducing its strength, and towards the understanding of the causes of cracking.

(*a*) *Theory of Rupture of Concrete.*—This project aims to define in terms of stress or strain the actual conditions for any complex loading at which concrete cracked. From short-term tests a criterion has been proposed which has received qualitative confirmation by more recent overseas work, and it is proposed to conclude formal work on this project.

(*b*) *Prehardening Cracks in Concrete.*—Random sporadic cracking of concrete within a few minutes of casting has been reported from field observations, and laboratory studies suggest that this prehardening, while only rarely developed to a sufficient extent to be readily visible, may be very widespread.

These cracks are caused not only by differential settlement of the concrete over obstructions such as reinforcement or large pieces of aggregate, but also by movement or vibration of the formwork near the time of initial set. Work has been carried out on sealing the cracks by vibrating or screeding the concrete and by using polyester or epoxy resins.

(*c*) *Restrained Shrinkage.*—Other than for prestressed units, the shrinkage of concrete is seldom important except for the stresses that may arise, with consequent chance of cracking, when it is restrained. From the behaviour of specimens of set cement paste and mortar in which shrinkage was partially restrained by a central steel rod, it has been found that the creep or flow of the mortar or paste under stress can greatly reduce the stresses which tend to develop, and may be sufficient to avoid cracking.

6. GLASS AND GLAZING.

(Division of Building Research.)

(*a*) *Cracking of Glass under Thermal Stress.*—Shading the edges of glass from direct sunlight by the beads and glazing compound holding it in place gives rise to thermal gradients across the edge. The resulting tensile stresses are often sufficient to cause cracking, particularly if imperfections are present at the edge. The effects have been studied of edge treatments and cutting techniques on the incidence of cracking. Only minor changes in resistance to thermal stresses can be achieved by different methods of treating the edges, although a major decrease in strength results when the edges are badly damaged.

The differences in temperatures between the centre and edges of glass exposed to the sun render the risk of cracking in black ceramic enamelled glass at least four times that for white ceramic enamelled glass.

(*b*) *Glazing Compounds.*—Improvements have been made to the shear and tensile tests developed for examining non-hardening glazing compounds. A cyclic movement tester has been developed to subject the shear specimens to the type of daily movement that might occur in practice. The performance of glazing compounds subjected to such dynamic exposure is being compared with that of the same materials subjected to natural and accelerated exposure.

7. GYPSUM PLASTER INVESTIGATIONS.

(Division of Building Research.)

Investigations are being made into the fundamental physical chemistry of calcium sulphate hemihydrate (gypsum plaster), the mechanical properties of plaster for use in load-bearing walls, and problems associated with the manufacture and decoration of fibrous plaster sheets.

Chemical engineering studies are also being undertaken on the manufacture of plaster from gypsum, and continuous pneumatic dewatering apparatus (15 tons per hour) for washed gypsum has been developed..

(*a*) *Physical Chemistry of Plaster.*—Work on the physical chemistry of plaster has been continued to gain clearer insight into the behaviour of plaster, and to obtain a better understanding of reasons for variability in behaviour. Other studies include: vapour pressure relationships of various forms of calcium sulphate, the nature of the difference between the alpha and beta forms of the hemihydrate, conditions under which these forms can be interconverted, the effect of changes in calcining conditions on the properties of the plaster and the basic reasons for these changes in properties, the mechanism of setting and hardening, and the relationship between the physical properties of plaster and its microstructure.

(*b*) *Structural Gypsum Plaster.*—The use of gypsum plaster as a load-bearing material raises the need for information on its deformation under long-term load. Tests to obtain this information have now been in progress on small beams for two years.

To establish the drying requirements to be satisfied before cast gypsum slabs can safely be decorated, the rate has been studied at which moisture is lost from slabs of different thicknesses, which have been allowed to dry from one side only.

(*c*) *Fibrous Plaster Investigations.*—Investigation of the problems of fibrous plaster manufacture is sponsored by the Associated Fibrous Plaster Manufacturers of Australia. The physio-chemical nature of the changes which gypsum undergoes are being studied from the time when it is mined to the final drying of the plaster sheet. Other problems that have been studied are: the effect of release agents and additives on the adhesion of paint films; the development of improved release agents; the development of special types of plaster; and the relation between the physical properties of plaster and its microstructure.

8. LIGHTWEIGHT AGGREGATES.

(Division of Building Research.)

For several years there has been a world-wide trend to lighter building construction, which has increased the demand for lightweight aggregates in concrete and plaster for structural and fireproofing purposes. Research has continued on the production and properties of these lightweight aggregates, notably on bloated clay and shale for concrete and perlite for both concrete and plaster.

(*a*) *Lightweight Clay and Shale Aggregates.*—The Division's earlier work on the potentialities of Australian resources of the raw material for clay and shale aggregate has come to fruition with the construction of three works—two near Sydney and one near Melbourne.

Aggregate for a demonstration concrete house built by the Victorian Housing Commission was produced in the Division's pilot plant.

Testing continues of raw materials for potential manufacturers.

(*b*) *Perlite.*—Perlite, commercially available in Australia for some years, is an ultralightweight aggregate made from volcanic glasses. Testing of raw materials and aggregates has been carried out for established and prospective manufacturers of perlite, but work on perlite itself has been confined almost entirely to advice and assistance to manufacturers and users.

9. PAINT ON PLASTER INVESTIGATIONS.

(Division of Building Research.)

Work on the decoration of plaster surfaces sponsored by the Australian Paint Manufacturers' Federation relates to problems arising from earlier investigation of the cause of sulphide staining. The chief one of these is the possibility that hydrogen sulphide in the atmosphere could reduce the effectiveness of mercury compounds added to paints as fungicides.

Tests have been carried out, in co-operation with the Defence Standards Laboratories, to determine the loss of fungicidal activity of sample paints exposed under natural and artificial conditions.

Attention has been given to the study of the adhesion of paint films, particularly measurement of adhesion, improvement of adhesion of p.v.a. paints under wet conditions, and the effect of water-soluble salts on adhesion.

10. STONE.

(Division of Building Research.)

The demand for stone for exterior and interior use has increased in all States of Australia, and has resulted in a greater number of inquiries regarding its availability and use. Most of the present day utilization of stone, as a decorative cladding and veneer rather than as a structural material as formerly, has been centred round granites, soft and hard sandstones (not necessarily freestones), soft and hard limestones, marbles, and slates of various types. All of these have presented problems relating to their performance and the Division has been approached for technical advice on the cause of the failures and remedial measures.

11. THERMAL INVESTIGATIONS.

(Division of Building Research.)

The Division's mathematical method for evaluating the internal temperature of a building exposed to variable external conditions has been greatly simplified by employing the CSIRAC automatic computer at the Physics Department of the University of Melbourne. Four different programmes for operating the computer have been devised and tested.

Research work on briquette-fired heating units sponsored by the State Electricity Commission of Victoria has made good progress. The practicability of using brown coal briquettes as fuel for combined systems of both space and hot water heating is being investigated to develop an effective system for domestic purposes.

A 65-point automatic pontentiometric recorder has been designed and constructed to record the test temperature data of the space heating studies on teleprinter tape for direct processing in the automatic computer.

XVI. WOOL.

1. GENERAL.

It is increasingly apparent that Australia must carry the major responsibility for wool textile research to meet the growing competition from man-made fibres. The Organization is paying special attention to problems of the wool textile industry to ensure that public demand is maintained for fabrics manufactured from wool, and to preserve wool's unique position among the world's textile fibres.

The Organization's wool textile research is designed (i) to increase knowledge of the complex structure of the wool fibre and of its physical and chemical properties, (ii) to use this knowledge to improve wool as a textile fibre, to improve technology in wool processing, and to utilize by-products more fully, and (iii) to improve the machinery used in wool textile manufacture.

The Organization's wool textile research is distributed among three laboratories situated in the main Australian textile manufacturing centres, Melbourne, Sydney, and Geelong:—

(1) The Division of Protein Chemistry, Parkville, Victoria, is responsible for research on the structure and chemistry of wool and industrial processes emerging from this work.

(2) The Division of Textile Physics, Ryde, New South Wales, is investigating the physics of wool fibres and assemblies, and engineering aspects of wool processing.

(3) The Division of Textile Industry, Geelong, Victoria, is responsible for technological investigations.

The policy of these Laboratories and the co-ordination of wool textile research is the responsibility of the Wool Textile Research Committee comprising the Chiefs of the three Divisions. This Committee reviews research programmes to ensure that for each project the best use is made of available staff and facilities. It also arranges where necessary for joint studies to be made on particular projects in two or in all three Divisions. The work of the Wool Research Laboratories is described in this Chapter.

This work is complementary to research in sheep husbandry described in Chapters V., VI., and VII. which is aimed to increase the quality and production of wool at the pastoral stage.

The Chemical Research Laboratories continued a study of constituents of wool wax and ways of utilizing them or their derivatives (see Section 4 of this Chapter). It is also studying the structure of proteins in relation to wool (see Section 10 of this Chapter). The Division of Entomology is continuing study of digestive processes of wool-eating insects and larvae (see Chapter IX., Section 2 (a)).

Wool Research Laboratories.—In recognition of the growing importance of textile research to the wool industry and of the high standard of work in progress in these establishments, divisional status was conferred on each of the Organization's Wool Research Laboratories in December, 1958.

During the year several recently developed wool textile processes have been established in industry. The SI-RO-SET process for permanently creasing and pleating, for example, has been widely adopted in Australia and overseas.

The use of dieldrin for mothproofing certain types of woollen goods has also extended overseas. The solvent degreasing process continues on a three-shift basis in an Australian mill, but there have been delays in construction of the plant being established in the United Kingdom. Research is continuing on alternative processes to worsted carding, and large-scale equipment is in course of construction. The Noble comb control unit is now being manufactured commercially and the first units are operating satisfactorily in Australian mills.

An Australian firm has been licensed, and is commencing manufacture of the electronic yarn evenness tester developed in the Sydney Division.

Research on the nature of dust in hospital wards, and on blankets, has induced the Royal Melbourne Hospital to change from wool-cotton union to all-wool shrinkproofed blankets, and to launder and sterilize them by boiling in a detergent preparation recommended by the Melbourne Division.

A project has been started to overcome pilling in wool knitwear. Emulsions of various synthetic resins are applied to knitted fabrics to retard migration of the fibres.

A new building for wet processing investigations has been completed at Geelong, and a comprehensive range of full-scale dyeing and finishing equipment installed. This will facilitate research on the production of wash-and-wear properties in pure wool fabrics.

The flow of information between the research scientist and others working for wool should be facilitated by the establishment early in 1959 of a Joint Technical Advisory Committee, comprising the Australian Wool Bureau's recently appointed Director of Promotion, the Director of the Australian Wool Testing Authority, and the Chiefs of the three C.S.I.R.O. Wool Research Divisions. It is planned, through this Committee, to integrate wool science, wool testing, and wool promotion in the best interests of the Australian wool industry.

It is desired to acknowledge the ready co-operation of woollen and worsted manufacturers who have taken part in industrial projects described in this report, of hospitals who co-operated in the blanket research project, of universities and similar institutes both in Australia and overseas, of the Gordon Institute of Technology, and of the Melbourne Textile Trades School.

2. RAW WOOL.

(Wool Research Laboratories.)

(*a*) *Sampling of Wool*.—The pressure corer method of sampling wool has been further developed. The corer is a tube with a sharpened tip which is pushed into wool bales when samples are being taken for testing purposes. It is an improvement on existing types which require an electric drill motor to help cut their way in. Designs and sharpening equipment have now been made available over the diameter range 0.4-1 in. to allow the selection of tube size to collect the right amount of wool for test.

(*b*) *Jute Contamination*.—Complaints have been received in Australia from wool textile manufacturers that their wool fabrics often contain jute fibres. These fibres do not absorb dye readily under the conditions used for dyeing wool, and in some mills they are laboriously picked out of the finished fabric with tweezers at considerable cost. The fibres may arise from loose jute strings in the bale, from short lengths of string released when the edges of the bale are cut on the show floor, from windows cut in the bale for inspection purposes, and from loose fibres on the surface of the jute fabric. As a first step to overcome this problem graziers are being asked to remove all loose string from bales before using them, and arrangements have been made for sample packs which have been impregnated with plastic to be supplied for test. These should minimize contamination with surface fibres from the jute fabric.

(*c*) *Significance of Tender Wool*.—Tender wool usually sells for a lower price at auction than sound wool, buyers anticipating loss of fibre length by breakage during processing. Actual losses in processing have been investigated with different degrees of tenderness. A mechanical strength test has been developed which is performed on a staple of wool in the greasy state.

(*d*) *Branding Fluids*.—SI-RO-MARK branding fluid continues to be widely used. During the year 112,566 gal. were produced and of this 43 per cent. was blue, 38 per cent. red, 17.5 per cent. green, and 1.5 per cent. purple. The branding fluid problem, as far as woollen mills are concerned, has been largely overcome. On the other hand, there have been reports of unsatisfactory field performance and research is in progress to overcome these difficulties. A fluid of higher viscosity is under test and various alternative branding implements have been employed to increase the amount applied to sheep. In other tests, the solids content of the fluid has been increased and ultraviolet absorbers added to reduce actinic degradation. The ideal branding fluid is a compromise between the two opposing requirements of high durability on the sheep and ease of removal in mill scouring. To obtain satisfactory field performance, full co-operation by users is essential to ensure that the fluid is correctly applied.

(*e*) *Solvent Degreasing*.—The quality of lanolin obtained from the solvent degreasing plant has been improved by an acid peroxide bleaching process now applied commercially.

Experiments have continued on the degreasing pilot plant to shorten the length of the unit by using fewer jets at higher pressure and substituting rotating drums for the wire mesh conveyor. The unit is being rebuilt along these lines and is being totally enclosed. The modified machine will be used to obtain more accurate data on solvent consumption and information on the functioning of a shortened unit.

Industrial trials have confirmed that improvements in tear are obtained with wool treated on the pilot plant; this has been compared with similar wool scoured by normal processes. The solvent degreasing process also gives a greater yield of wool than alkaline soap scouring. Fibre is removed from staple tips during alkaline scouring, and this goes to waste either in solution or suspension. Such wastage does not occur in solvent degreasing and a higher yield of fibre is obtained. This was first noticed in commercial trials and has now been confirmed in controlled tests. Percentage increase varies with the type of wool and with the degree of weathering of the tip of the fleece.

3. FLEECE BY-PRODUCTS.

(Wool Research Laboratories.)

Research on wool wax has been concerned with the development of a simple and cheap method of saponifying lanolin, to recover the alcohols from it which have higher commercial value than the original lanolin. An additional flotation recovery unit for lanolin has been installed making five commercial units now in operation in Australia.

4. DERIVATIVES OF WOOL WAX AND SUINT.

(Organic Chemistry Section.)

(*a*) *Wool Wax.*—Selected esters of the total acids of wool wax have mechanical properties suitable for their use as secondary plasticizers for polyvinyl chloride, but are unacceptable owing to severe bleeding. Alpha hydroxy acids form 30 or more per cent. of the total acids, and as acetylated butyl esters do not bleed from the blended plastic and can replace 30 per cent. of the dioctyl phthalate normally employed. The hydroxy acids can be separated from the remainder by liquid-liquid extraction.

Colouring matter of wool wax from solvent scouring has been studied. Sulphur originating in sheep dips causes discoloration of wax when exposed to heat or light. Another material developing colour on exposure to heat or light is present in most fleeces or is formed during the normal weathering of fleeces. Its identification is being sought.

Lanosterol is a large part of the non-acidic material in wool wax. Many derived chemicals have been made and evaluations made of those with hormonal activity. Most of these and related steroidal compounds were tested for anti-tumour activity by the National Cancer Institute, U.S.A. Some ketoacetates derived from lanosterol are suited to studies of insulated groups exerting influences at remote positions within a molecule. A carbonyl group at the 3 position affects reactivity at the 11 position, although separated from it by at least four carbon atoms.

(*b*) *The Acids of Suint.*—Suint forms a large proportion of some fleeces and consists principally of potassium and other salts of organic acids. There is little exact knowledge of the nature of these acids. Suint was extracted from seven different wools, and the acids present converted to their methyl esters and examined chromatographically. Each mixture of acids was complex with indications of up to 40 acids present; the mixtures differed considerably, both qualitatively and quantitatively.

5. WOOL TEXTILE PROCESSES.

(Wool Research Laboratories.)

(*a*) *Carding.*—Work continues on the convertor system, and a full-scale prototype is under construction. New approaches are being made to the problem of removal of vegetable material.

Research on worsted carding and combing has been intensified. The addition of small percentages of modified mineral oils to wool before carding can increase the yield of top by up to 2 per cent. depending on the residual wax content of the scoured wool.

For wool containing small quantities of vegetable matter, increasing the number of burr beaters on the card causes a redistribution of losses, card losses being increased, noil losses being decreased, and total losses remaining constant. Soap scoured wool usually carded at 45 lb./hr. can be carded satisfactorily at rates up to 75 lb./hr. with suitable card roller settings and speeds. The same wool, solvent degreased, can be carded satisfactorily at 125 lb./hr.

(*b*) *Combing.*—The comb control unit is now operating commercially in Australian mills. The unit has made possible experiments on Noble combing which have led to new findings. Variations in combing rate and tear under normal combing conditions are due to fluctuations in setover and not, as usually assumed, to differing proportions of short and long fibres in the wool being combed. Setover has little influence on fibre length distribution in the top, contrary to the usual assumption that combing removes all fibres shorter than a value fixed by the setover.

Increase in weight per unit length of sliver fed to the comb gives higher production, if the setover is constant, or higher tear if the production is constant. Increased regain of wool also gives higher comb tears. Increased comb speeds give increased production with no change in tear, limitation of speed being mechanical.

(*c*) *Dyeing.*—The melange printing process for tops is being tested for printing of fabric. No pretreatment of fabric is required and shorter steaming times can be employed.

Patterns can be printed on wool cloth by irradiation through a stencil with ultraviolet light, followed by dyeing of the whole cloth. Irradiated parts take up dye more readily than other parts and a variety of two-tone patterns can be produced. Ultraviolet irradiation is also suitable as a pretreatment for the whole cloth before silk-screen printing. It promotes penetration of dyes into wool from printing paste and can thus replace chlorination usually applied before printing wool. In the present state of development the process is not likely to be adopted widely because the costs of irradiation are a little too high.

Further studies on the cold solvent dyeing process, based on the application of dyestuffs to wool in formic acid solution, have shown its effectiveness to be largely due to swelling of the wool fibres by the acid and consequent lowering of the barrier to diffusion of dye into the fibre. When washed in water after the dyeing operation the swelling is reversed. Acid dyes, milling acid dyes, and the 1:1 metal-complex dyes have been applied to wool by this method. Since formic acid facilitates ionization of basic groups, but not of acidic groups in wool, basic dyes cannot be applied by this method. The process may find application in dyeing loose wool and tops, and for screen printing wool fabrics without chlorinating the wool or steaming the printed fabric. However, commercial applications of the method will depend largely on development of a cheap method of recovering formic acid for reuse.

6. FINISHING PROCESSES.

(Wool Research Laboratories.)

(*a*) *Shrinkproofing.*—The waxy substance on the surface of wool which interferes with shrinkproofing is a complex mixture of residual lanolin compounds which are strongly adsorbed by the fibre and can be removed with difficulty in certain organic solvents. To study the mechanism of shrinkproofing, scales taken from fibres before and after treatment are being analysed. A method based on ultrasonics has been developed for removing the scales for analysis.

Shrinkproofing by means of oxidizing agents in the presence of strong salt solutions has been developed to pilot scale using potassium permanganate as the oxidizing agent. The solution can be applied to the wool fabric on a winch. Research is also in progress on reducing agents in shrinkproofing and on the application of resins and proteins to the wool.

(*b*) *Mothproofing.*—The method based on dieldrin emulsions has been widely adopted overseas. Further assistance has been given to firms using the process, which appears to provide an economic answer to the problem of moth attack.

(*c*) *Permanent Pleating.*—Use of the SI-RO-SET process extended overseas and is in commercial use in the United Kingdom, Europe, America, New Zealand, and Japan. Four firms in addition to the previous eighteen have been licensed to use the process in Australia and several major manufacturers are applying it extensively. To assist users of the method, most of the leading dye manufacturers have tested their shades for fastness to the SI-RO-SET treatment and have provided the results to mills.

The amount of felting movement or migration of fibres needed to spoil a pleat during washing is quite small, of the order of 0.5 mm., and such movement has been termed "microfelting".

Mechanical tests on pleated fabrics have established the relationship between the original pleat angle, fabric stiffness, and the removal of the pleat when the fabric is pulled at right angles to the line of the pleat. Extensions were proportional to the reciprocal square root of the load applied. This may help design of cloth for pleat retention.

(*d*) *Dimensional Stability of Cloth.*—Although shrinkage of wool cloth due to felting can be almost eliminated by shrinkproofing treatments, there are other important sources of dimensional change. One of these is relaxation shrinkage on release by wetting of temporary set caused by stretching wool in some preceding process. Another is hygral expansion which can show as an increase or decrease in size, and is due to moisture content of cloth changing with relative humidity and causing fibres to bend and straighten. The causes and extent of cloth shrinkage are being investigated with the co-operation of five Australian mills, each of which has supplied seven types of cloth.

(*e*) *Wash and Wear.*—To develop wash and wear effects in pure wool fabrics they are treated with a shrinkproofing process followed by a flat setting operation to permanently set the fibres and confer a non-iron effect. Treatment of shrinkproofed fabric with a solution of sodium bisulphite, followed by steaming on the blower, provides sufficient surface setting to give such an effect and many types of fabric, shrinkproofed and set in this way, have now been tested in the form of garments. In a large-scale wearing trial on shirts of treated fabric very satisfactory performance was obtained. Shirts washed more than 100 times without ironing in this trial are still satisfactory and retain a good appearance. Fabric structure has an influence on such effects and must be considered, in addition to pattern and colour. Effects are being studied of such variables as cloth structure and yarn twist on the wash and wear properties.

(*f*) *Laundering and Sterilization of Hospital Blankets.*—Dust collected at bed-level in hospital wards contained mainly cotton fibres and other forms of cellulose. Wool blankets are therefore unlikely to contribute significantly to hospital cross-infection by release of bacteria-laden wool fibres. Nevertheless, like other materials in the ward, they should be cleaned and sterilized frequently. All-wool blankets possess greater abrasion resistance than the commonly used wool-cotton blankets and they are easier to free of stains. Following experience in New Zealand with a boiling method of sterilizing all-wool blankets a similar method has been investigated. It has been modified to overcome discoloration during repeated treatment, and boiling of shrink-proofed all-wool hospital blankets in a solution of triethanolamine dodecylbenzenesulphonate containing a trace of sulphur dioxide has been recommended and adopted for hospital use.

7. PHYSICS OF WOOL AND FIBRE ASSEMBLIES.

(Wool Research Laboratories.)

(*a*) *Mechanical Properties of Single Fibres.*—Retention of threads in a curved form in woven wool fabrics and in pleats, and maintenance of good surface appearance are achieved by "setting" individual wool fibres in an extended or bent form by physical or chemical treatments.

The stress remaining in fibres after setting at a fixed extension at various temperatures changes in the region of 60-70° C. Below this transition temperature, stress is due to stretched bonds; above it, to chain segment motion as in stretched rubbers. Marked decrease in optical birefringence occurs at the transition temperature.

When fibres are extended in water at temperatures below transition temperature change from the "yield" to "post-yield" regions always occurs at about 30 per cent. extension. Above transition temperature extension at which this change occurs increases with temperature. It appears prerequisite for permanent setting that some region of the wool fibres can undergo a second-order transition. This is being applied to a study of the setting of wool by a variety of methods.

The transition temperature can be altered drastically by physical or chemical treatments such as the SI-RO-SET process in which treatment with thioglycollate reduces the transition temperature to less than 20° C.

When a dry wool fibre takes up moisture the torsional rigidity falls and reaches a mimimum when most of the water penetration has occurred. Rigidity then increases for several hours. These effects may result from an initial process akin to solution followed by a sol-gel transformation. Concomitant changes in longitudinal stress and electrical conductivity support this explanation.

(*b*) *Electrical Properties.*—Irradiation of Corriedale wool with ultraviolet light did not change electrical resistance. This, together with the concept of sol-gel transformation, suggests that proton rather than electron transfer is responsible for electrical conductance in wool.

(*c*) *Regain in Wool.*—The "dry weight" of wool varies with the relative humidity to which it has been exposed and the temperature of drying. Vacuum dry weight falls steadily with increasing temperature to about 140°, remains constant from 140 to 160° C., then decreases irreversibly due to decomposition. In a study of size of dryers, control of regain, and running cost of wool dryers, the rate of equilibration of wool with air blown through at constant relative humidity is not increased by raising the temperature. Hence with this method of controlling regain cold air would be as effective as hot air. Over-drying followed by reconditioning may achieve a desired regain more rapidly than the normal method of progressively drying wool to this approximate value.

(*d*) *Movement of Fibres in Drafting.*—During drafting fibres take up all velocities intermediate between back and front roller velocities, and can accelerate and retard several times in the drafting zone.

8. STRUCTURE OF WOOL FIBRE.

(Wool Research Laboratories.)

(*a*) *Wool Root Biochemistry.*—Investigations on wool and hair at the site of synthesis in the follicle have confirmed the presence of the amino acid citrulline combined in the fibrous protein of the inner root sheath. In hair follicle protein it represents approximately 6 per cent. of the material. It may be important in wool synthesis and could be formed by de-imidation of arginine residues.

(*b*) *Direct Examination of Fibre.*—Electron microscopy of ultra-thin sections of wool, obtained by using the new araldite embedding technique, has revealed spaces between the cells in cortex and cuticle up to 300 Å. wide containing cementing material. Protein which stains readily with osmic acid is also revealed between the fibrils. After reduction under conditions which allow the (A + B) cystine links to be split followed by prolonged osmic acid staining, the presence of sulphur-rich matrix protein can be demonstrated between microfibrils. Microfibrils are about 60 Å. in diameter and are spaced about 87 Å. apart. In the paracortex they are packed together in a near-hexagonal array but in the orthocortex they occur in the form of spiral aggregates. The spacing between the microfibrils calculated from low-angle X-ray diffraction patterns of wool agree well with electron microscope results. Diffraction patterns following reduction and treatment with methyl mercury iodide indicate that the (A + B) cystine residues occur in the matrix.

X-ray diffraction patterns on wool before and after uptake of moisture were considered in conjunction with infra-red absorption spectra after treatment with deuterium oxide and also in conjunction with absorption of moisture after supercontraction in cuprammonium hydroxide and after reduction and substitution of the (A + B) disulphide bonds. Moisture absorbed by wool appears to be taken up mainly by the matrix and very little penetrates into the microfibrils. Comparison of mechanical properties of wool in the dry and the wet state indicates the presence of a water-absorbing matrix in which non-absorbing cylinders are embedded, that is, for the matrix-microfibrillar type of structure. This model has been used to explain for dry and wet wool the relationships between Young's modulus, torsional modulus, the difference between transverse and longitudinal diffusion, and aspects of changes in electrical conductivity on stretching. X-ray evidence and results of amino acid analysis of proteins from the microfibrils and matrix show that amino acids with bulky side chains such as tyrosine are not confined to the matrix, as claimed by previous workers, but occur also in microfibrils.

Quantitative infra-red studies of hydrogen-deuterium exchange reaction in wool suggest that some hydrogen atoms involved in peptide linkages in microfibrils do not react. All potentially replaceable hydrogen atoms in side chains do react.

The low angle X-ray diffraction pattern obtained with keratin after staining with osmic acid shows maxima at 36, 45, and 28 Å, attributed to shape and packing arrangement of microfibrils. It also shows a group of reflections at 9.8 Å. attributable to the contents of microfibrils.

Amino acid analyses have been made of two cortical cell fractions prepared by research workers in the United States by soaking wool for 50 hours in 6N hydrochloric acid at 30° C., beating in a Waring blendor, and centrifuging in a solution of chloral hydrate. The heavy fraction, representing 20 per cent. of the wool, contained higher concentrations of amide nitrogen, cystine, serine, and proline than the light fraction which represented about 26 per cent. of fibre.

Techniques for physical experiments on component parts of wool fibre have been advanced by development of a method for accurately grinding down a single fibre to a cylinder of smaller diameter. This has been used successfully to study changes in properties of wool fibres due to penetration by ultraviolet light, and to reveal differences between the orthocortex and paracortex.

Study of mechanical properties of wool fibres which have undergone first and second stage supercontraction in concentrated lithium bromide solution suggests that two series zones of different accessibility or reactivity are present. One zone is associated with transition occurring during permanent setting, the other with that part of the fibre which " yields " during a load-extension test.

(*c*) *Examination of Extracted Proteins.*—The wool protein derivatives, *S*-carboxymethylkerateine 2 and α-keratose, extracted from wool following reduction and oxidation of the disulphide bonds respectively, have been further studied. Aggregation of these protein derivatives occurred in solution while standing, thereby lowering viscosity and increasing turbidity. Disaggregation occurred on dilution and in the presence of alkali, sodium dodecyl sulphate, acetic acid, urea, and granidine. Less disaggregation occurred in the non-aqueous acids, formic acid and dichloroacetic acid. Examination of the moving-boundary electrophoresis pattern of mixed *S*-carboxymethylkerateines from wool has shown that the pattern is unchanged by adding urea or sodium dodecyl sulphate to the alkaline thioglycollate solution to assist extraction. Proteins extracted from wool with cuprammonium bisulphite solution, which converts each -S-S- bond into two -SO_3 groups, have been named *S*-sulphokerateines. These derivatives, and also protein derivatives extracted with urea bisulphite, give electrophoresis patterns resembling those for the *S*-carboxymethylkerateines and they likewise show the presence of at least four components.

The maximum amount of some acid dye anions bound on *S*-carboxymethylkerateine 2 is less than that equivalent to the number of basic side chains on the protein revealed by analysis. The guanidino groups of the arginine residues seem unable to bind these ions because they are more firmly bound to other groups on the protein.

Extraction of wool with alkaline thioglycollate solution yields two proteins having lower sulphur contents than wool. Associated with the more readily extractable of these two is a protein fraction having a much higher sulphur content than wool and showing three peaks on electrophoresis. It also shows two main peaks and several minor ones when run by gradient elution on a *N,N'*-diethylaminocellulose column.

A new method of preparing soluble wool proteins has been developed based on reduction of disulphide bonds with sodium borohydrite at pH 10-11. After only 1 hr. at 20° C. some 90 per cent. of the wool was dissolved with this reagent and the product has been readily converted to the *S*-carboxymethyl derivative with sodium iodoacetate for further characterization.

(*d*) *Estimation of Amino Acids.*—Equipment for estimating amino acids in wool and wool proteins is now fully automatic and has been modified to run eight ion-exchange columns simultaneously into a single photoelectric colorimeter. A printing mechanism records absorption values of successive fractions on paper strips to eliminate the necessity for taking readings from recorded curves.

A further improvement in the amperometric method of estimating thiol and disulphide groups in wool has been made based on treatment with excess mercuric chloride in the presence of sulphite and urea at pH 9. After 18 hr. thiol plus disulphide groups are determined by measuring the excess mercuric chloride. Thiol groups are estimated separately using methyl mercury iodide instead of mercuric chloride.

9. Wool Protein Chemistry.

(Wool Research Laboratories.)

(*a*) *Studies on Wool Fibre.*—Attempts have been made to introduce additional peptide bonds into wool by reaction with bis*cyclo*hexyl carbodiimide to convert salt links into amide cross-links. The solubility and bond extension properties of fibres indicate little cross-linking, and the nature of the reaction is obscure.

In the reaction of wool with anhydrous acids in relation to the damage suffered by wool in carbonizing, hydrogen chloride acts at the serine and threonine residues. They undergo acyl migration, are involved in oxazoline ring formation or esterification, or may be partly or completely split from the chain. Sulphuric acid causes similar but more limited reactions. In studies of varying reactivity in disulphide groups in wool the special reactivity of subfraction A may be due to ionized carboxyl groups in the vicinity.

(*b*) *Studies with Model Compounds.*—Studies on the synthesis of cystine-containing peptides have shown need for special care when saponifying certain *N*-benzyloxycarbonyl peptide sequences. Urea or hydantoin-3-acetic acid derivatives are formed under certain conditions.

The preparation of benzyloxycarbonyl-2-iodoethylamine and similar compounds and their polymers has been described. Side chains of such polymers resemble those of lysine and the adjacent peptide bonds are therefore hydrolysed by trypsin.

10. PROTEIN STRUCTURE.

(Division of Chemical Physics.)

X-ray examination is made of simple peptides to obtain information on structure of the units from which proteins are built. Need for high-purity intermediate products has prompted investigations of counter-current liquid-liquid extraction processes operating under reflux. In this method both liquid phases travel. The first process, " dissociation extraction ", was applied to the separation of penicillin acids some years ago in the Division of Physical Chemistry by using a column in which the solvents were in continuous flow. Intermittent flow attainable in the tube system at present under study results in greatly increased separation efficiency. The process is analogous to fractional distillation, the most important practical factor being equilibration time, which is at present under investigation. The second process effects separations by partition alone and is in some way complementary to the Craig method.

X-ray analysis of tosyl-L-prolyl-L-hydroxyproline monohydrate, initially carried out in two dimensions, has been extended to three dimensions, and the results provide a detailed picture of the sequence -L-prolyl-L-hydroxyproline.

Analysis of the peptide unit, L-leucyl-glycyl-glycylglycine, has started, but a peptide of antibiotic interest, valinomycin, was unsuitable for detailed study.

Tests on image-seeding methods have been made on one compound and their usefulness examined when applied to unknown structures. To permit as direct an analysis as possible the maximum possible diffraction data are collected using the high-power generator and working at —150° C. Thus for jacobine bromhydrin, 3,400 independent reflexions were measured, and the bromine atoms located from the three-dimensional vector distribution. With these atoms as the search group a three-dimensional image-seeking distribution has been completed, from which will be sought the 56 atoms corresponding to the two molecules in the asymmetric unit.

Refined atomic scattering curves (*f*-curves) have shown significant errors in earlier *f*-curves available for important " heavy atom " members in structure analysis. The new results define modifications of free-atom scattering power found in detailed electron distribution studies, and detention of this modification in NaCl structure is to be examined. The result for sulphur was used, in conjunction with scattering curve data obtained from structure analysis of thiophene and orthorhombic sulphur, to demonstrate that experimental derivations of scattering power are valid only if the condition of absolute scaling in X-ray diffraction data is stringently satisfied. The results obtained for chlorine and sulphur were used to obtain an *f*-curve for phosphorus which is more satisfactory for structure analysis than results previously available for this atom.

11. GENERAL PROTEIN INVESTIGATIONS.

(Wool Research Laboratories.)

Measurements of infra-red spectra of kangaroo tail tendon have shown that one absorption band due to sorbed water is dichroic. Such water may be linked through hydrogen bonds to some -CO groups in collagen which project outwards from the triple chain model, the preferred orientation of water molecules being with length at right angles to the tendon axis.

The effect was studied of formic acid on the viscosity of bovine serum albumin and on its light-scattering properties in research on the disaggregating effect of certain organic solvents on proteins.

A claim that oxidized serum albumin contains large amounts of *N*-terminal cysteic acid was investigated but not substantiated. Aspartic acid is the only *N*-terminal amino acid present and it occurs at a concentration corresponding to one mole per mole of the protein.

12. BIOLOGICAL DEGRADATION OF CELLULOSE.

(Wool Research Laboratories.)

The β-glucosidase activities of filtrates from shake cultures of fungi have been measured but no evidence was obtained for classifying them into separate groups. Differences between them appear random.

Digestibility of untreated tissues and of cellulose preparations from various plants by *Cellulomonas* has been studied in relation to their structure and composition.

Research on the cellulose degradation project is being linked with the protein research programme in the Melbourne Division. Attention is being given, for example, to the purification of β-glucosidase enzymes from *Stachybotrys atra* using ethanol fractionation and chromatographic techniques of protein chemistry.

XVII. CHEMICAL RESEARCH.

1. GENERAL.

Many Australian natural resources are unique to this country, and in adapting these to the uses of modern technology, problems arise which are peculiar to Australia. Our economic future depends on the initiative with which Australian scientists meet the challenge of developing uses for these resources.

The Chemical Research Laboratories, formerly the Division of Industrial Chemistry, constitute the major concentration of chemical research within the Organization, although much chemical work is undertaken in other Divisions and Sections.

The terms of reference of the Laboratories are:—(a) to promote technical efficiency in established industries; (b) to stimulate establishment of new industries; (c) to encourage use of raw materials of Australian origin; (d) to seek substitutes for imported materials; (e) to find uses for by-products not utilized; and (f) to study national problems to which its officers can contribute by virtue of their experience in other fields.

This Chapter describes the work of the Chemical Research Laboratories. The study by the Organic Chemistry Section of the constituents of wool wax and utilization of them is described in Chapter XVI., Section 4. The work of the Division of Chemical Physics on study of proteins in relation to wool is described in Chapter XVI., Section 10. The work of the Chemical Engineering Section on the utilization of brown coal is described in Chapter XIX., Section 5.

Chemical Research Laboratories.—Three former sections, Chemical Physics, Physical Chemistry, and Minerals Utilization, are now classified as the Divisions of Chemical Physics, Physical Chemistry, and Mineral Chemistry respectively. The remaining sections, Organic Chemistry, Cement and Ceramics, and Chemical Engineering, are now independent sections of the Organization, their Officers-in-charge, like the Chiefs of the three Divisions, being responsible to the Executive through the Director of the Chemical Research Laboratories (see Chapter I., Section 6). This change in status has been effected in such a manner as to preserve the unity of the Laboratories and to safeguard the many advantages of close collaboration between specialists in different disciplines.

The policy is being continued of including in the research programmes a blend of basic investigation along with that work which is directed specifically to the solution of particular practical problems. This policy has yielded significant results in the past, and is regarded as the most effective means for contributing to national development.

Among the many offices held by members of the Laboratories in professional and learned societies, Dr. I. W. Wark continued as the Chairman of the Victorian Group of the Australian Academy of Science; Dr. H. H. Hatt was President of Section " B " of A.N.Z.A.A.S. for the Adelaide Conference; Mr. H. A. Stephens is President of the Australian Association for Corrosion Prevention; and Dr. A. Walkley is Honorary General Secretary of the Royal Australian Chemical Institute.

Research projects have continued in co-operation with industrial and other establishments. Recently the Division of Mineral Chemistry has undertaken investigation of aspects of gold cyanidation on behalf of the Western Australian Chamber of Mines. The continuation of research on evaporation control by the Division of Physical Chemistry, and particularly large-scale field tests, has been possible through the generous assistance of the Broken Hill Water Board, the State Rivers and Water Supply Commission of Victoria, and Rio Tinto Management Services. Research on bushfire control has been aided by the ready co-operation of many agencies, both State and Commonwealth, and of private companies. Other co-operative projects reported previously are continuing.

The Laboratories have provided assistance by way of consultation and the use of special facilities to a large number of establishments and individual inquirers.

2. MINERAL CHEMISTRY.

(Division of Mineral Chemistry.)

The main objective of the Division of Mineral Chemistry is the chemical transformation of Australian minerals into various derivatives of actual, or potential, industrial use. While the Division undertakes research on the industrial utilization of minerals through adaptation of their intrinsic physical properties the importance of fundamental studies is also stressed. Mineral chemistry may be said to involve not only the recognized disciples of inorganic and physical chemistry, but also such aspects of geochemistry and biogeochemistry as concern many mineral transformations.

A number of research projects reached a conclusion during the past year. Those concerned with the hydrometallurgical extraction of copper, uranium, and lithium and some others fall within this category. New projects were commenced or techniques applicable to former investigations were adapted to new themes.

(*a*) *Electrode Processes.*—Electrode reactions of metallurgical interest may be modified by small additions of apparently unrelated substances. These catalytic effects may appear in the purity of the deposit or in the power consumed in electrolysis. Evolution of oxygen at a lead electrode, an important source of power wastage in many metallurgical operations, was studied kinetically and the effect of cobalt on overvoltage measured. The actual decomposition of a water molecule is the normal rate-determining step, whereas when cobalt is present it is probably adsorbed on the lead dioxide surface as a cobalt (III)-aquo complex whose breakdown to cobalt (II) with evolution of oxygen becomes the rate-determining step and the overall process is faster. Similarly the behaviour of molybdenum (VI) in lowering the overvoltage of copper deposition from solutions of acidified copper sulphate has been attributed to formation of a preferentially adsorbed Cu-Mo complex which assists the discharge mechanism and simultaneously permits molybdenum to enter the copper deposit. Very small concentrations of chloride prevent molybdenum from influencing overvoltage and entering the deposit.

(*b*) *Hydrometallurgy of Bismuth.*—Bismuth occurs as a minor constituent of calcines from fluidized-bed roasting of chalcopyrite concentrates from the Peko mine in the Northern Territory. The growing importance of bismuth metal in nuclear engineering has stimulated investigation on selective leaching for separating it from copper and lead which are also present. This was accomplished by suitable combination of hydrogen ion, chloride ion, and sulphate ion concentrations in acidified brine leach. Leaching was followed by precipitation of bismuth oxychloride, reduction of the latter to metal, and electrorefining of this in aqueous electrolyte. The scale of the operation was such that about 60 lb. of calcines were leached. The only significant impurity found in the refined bismuth was silver ($<$0.1 per cent.), and the content of the most objectionable impurity, cadmium, was very low ($<$0.001 per cent.).

(*c*) *Hydrometallurgy of Gold.*—Cyanidation for the extraction of gold has changed little over the years and, being complex and little understood, is necessarily conducted on empirical lines. When the feed contains sulphides or products of the roasting of sulphide minerals, many impurities enter the solution which may lead to sudden and unpredictable gold losses. An agreement was recently reached with the Chamber of Mines of Western Australia, representing the four major gold producers of Kalgoorlie, who will finance an investigation into these losses. Initially oxygen content of solutions is being studied and its change with operating conditions and varying feed composition.

(*d*) *Analytical Procedures.*—Previous investigations on hydrometallurgy have shown the value of rapid polarographic and spectrophotometric procedures for process and laboratory control. A large proportion of the time required in many studies in mineral chemistry is spent in analysis. The chemistry of the analytical methods themselves is often so closely related to the chemical problem under consideration that analysis may form an integral part of the whole investigation. Attempts were made to determine oxygen polarographically in cyanide solutions charged with impurities occurring in plant practice. Rate of change of oxygen content during gold leaching is very rapid, especially in the presence of sulphides, and speed is an important factor. Investigations were commenced on rapid methods for the determination of other constituents such as cyanide and gold. Methods were studied of determining traces of molybdenum in metallic copper and in the raw materials of copper leaching procedures, and a reliable method was developed of considerable range and versatility.

(*e*) *Germanium Extraction.*—Work on the recovery of germanium from flue dusts from coal-fired power stations has been completed. As the average grade of flue dust available for treatment is 0.01-0.02 per cent. germanium economic factors have placed limitations on recovery techniques that might otherwise be suitable. Several simple leaching processes found to remove germanium successfully were rejected for economic reasons or owing to the variable response with flue dusts of similar type from different sources.

The most satisfactory process developed involved a preliminary sintering of flue dust with sodium chloride such that under the conditions chosen no volatilization of germanium occurred, but a fraction of silicate components was converted to a form soluble in acid. On leaching with dilute acid, extraction yields of 50-80 per cent. of germanium in different dusts could be obtained without dissolving more than 2 per cent. of silica or 4 per cent. of alumina present in the dusts.

Recoveries from aqueous extracts showed that tannin as a precipitant gave high yields of germanium (>90 per cent.) at pH values not substantially different from those produced in leach liquors. Tannic acid would be too costly for such a technique, but several commercial tannins were equal in efficiency to tannic acid at approximately one-tenth of the cost. Ashed tannin concentrates containing more than 10 per cent. GeO_2 were readily obtained.

(*f*) *Extraction of Uranium from Monazite.*—Less collaboration with the Australian Atomic Energy Commission and private companies has been required in uranium investigations and the only major topic studied was the selective extraction of uranium from monazite. The preferred procedure employs a fritting technique at temperatures in the range 850-1,000° C., with a flux of sodium sulphate and sodium fluoride mixed with finely ground monazite. The frit is leached with very dilute acid, recovering up to 60-70 per cent. of the uranium in solution, while leaving up to 95 per cent. of monazite unattacked. After recovery of dissolved uranium by solvent extraction, the liquors can be evaporated to recover the fluxing salts for treatment of fresh monazite. The process has been tested on laboratory scale with various monazite samples from Australia and India.

(*g*) *Pressure Digestion of Sulphides.*—Studies have continued on the oxidation of sulphides, attention being given to the behaviour of pyrrhotite under varied conditions of temperature, pressure, acidity, and particle size. Pyrrhotite is a common lode mineral, frequently associated with finely disseminated valuable minerals which can be liberated and recovered only by complete or partial decomposition of the pyrrhotite. Special interest attaches to the course of the decomposition reaction which determines whether sulphuric acid or sulphur is produced.

(*h*) *Acid Alumina Process.*—It was previously found that aluminium sulphate did not readily hydrolyse in pressure equipment, even at temperatures as high as 200° C., unless the solutions were made more basic by addition of alkaline materials, removal of sulphate ions, or dissolution of extra alumina. The two latter procedures are preferred since they do not lead to contamination of the hydrolysis product when caustic soda is used to prepare more basic solutions.

With the increased interest in aluminium production in Australia, following discovery of extensive bauxite deposits at Weipa in northern Queensland, the possibility was examined of utilizing the pressure hydrolysis technique as a stage in an acid process for making pure alumina. Such processes studied in the past have failed to compete with the alkaline (Bayer) process in purity of product or economy of operation.

A high-grade aluminium compound can be produced from bauxite, using pressure hydrolysis as the final stage. Impurities such as silica and iron are below the maximum specified for alumina used in making aluminium metal, provided that no ferric iron is present and that oxygen is excluded from the hydrolysis vessel.

A complete acid process was developed starting with bauxite and finishing with pure alumina, using pressure digestion as the essential unit operation for dissolution of bauxite, basification of digestion liquors, and subsequent hydrolysis to yield a pure basic aluminium sulphate. The only additional stage required is calcination of the hydrolysis product to remove the sulphate radical. Several novel features have been introduced, principally in basification and hydrolysis.

(*i*) *Extraction of Thorium and the Carbide-Iodide Process for High-purity Thorium Metal.*—Although thorium is used in increasing quantities in light metal alloys, worldwide interest in the metal stems largely from the potentialities of the thorium, uranium-233 fuel cycle for generation of nuclear power.

Deposits of thorium-bearing minerals in Australia are probably adequate for future Australian requirements, but a critical review of the numerous extraction processes used in other parts of the world, or proposed for future use, revealed deficiencies in most of them. These deficiencies are most apparent in stages of the process between decomposition of the thorium concentrates and final purification of thorium, for which solvent extraction is an accepted technique. Means have been sought to overcome these difficulties and to narrow the choice of process to not more than one of two suitable for adoption in Australia.

All processes referred to pertain to production of thorium intermediates such as thorium oxide or a thorium salt. Although the oxide and several other thorium compounds are suitable, after fabrication, for use in some types of nuclear reactor, there is a demand for thorium metal and its alloys. Processes exist for reducing the oxide, fluoride, or chloride to the metal, but all produce powdered, granular, or sponge metal heavily contaminated with impurities such as oxygen, carbon, and certain metals. Work has continued on the new process for producing thorium rods of the highest purity.

The newly developed " carbide-iodide " process has been evolved from the Van Arkel-de Boer process originally used to refine crude metals such as titanium and zirconium. Thorium carbide, which is easily and cheaply prepared, is used directly to produce thorium metal without intermediate formation of expensive crude metal. The process involves intermediate formation of volatile thorium iodide by interaction of thorium carbide and iodine and subsequent thermal decomposition of vaporized iodide on a heated surface. The rate of the process compares favorably with that obtained with crude thorium metal and other metal feed materials. The high degree of purification obtained is greater than that in the original Van Arkel-de Boer process because a number of elements are removed during the formation of the carbide.

Consideration has been given to scaling up the process. With the elimination of so many impurities, the highest-purity raw materials usually mandatory for production of nuclear grade metal, especially materials very low in rare earth elements and traces of phosphorus, need not be employed in the carbide-iodide process. Impurities commonly met in thorium intermediates, even after extensive chemical processing, are completely eliminated in the carbide-iodide process.

The carbide-iodide process may also have application in the decontamination of thorium irradiated in a nuclear reactor. Much higher " decontamination factors " can be obtained than in many pyrometallurgical processes currently under investigation for the purpose. The scheme proposed is based on a small number of steps in a cyclic process involving thorium dicarbide, thorium metal, and. if desired, other thorium compounds such as thorium monocarbide or thorium fluoride. Such a scheme would be suited to a system where dilute solutions of uranium in thorium were irradiated in metallic or other forms to consume fissile material at a rate comparable to that at which uranium-233 would be produced in the fuel element concerned.

A report embodying results of this work was presented at the Second International Conference on the Peaceful Uses of Atomic Energy held in Geneva in September, 1958.

(*j*) *Reactions with Atomic Gases.*—Apparatus was installed for investigation of reactions with atomic gases. This consists of a valve amplifier capable of providing up to 1 kW. of power at frequencies up to 30 Mc/s. The amplifier is crystal-controlled for stability and is driven by suitable frequency-multiplier and pre-amplifier stages. The optimum conditions for the production of single atoms of oxygen and hydrogen were first determined. A study was then made of gasification of carbon by oxygen, hydrogen, water vapour, and carbon dioxide. These gases were respectively broken down in the high frequency field to oxygen atoms, hydrogen atoms, hydrogen atoms with hydroxyl radicals, and carbon monoxide with oxygen atoms. In the oxidation of carbon, carbon monoxide is the primary product; this may react further with oxygen to produce carbon dioxide. The above reactions take place readily at room temperature and the investigation has thrown considerable light on the mechanisms of normal gasification processes and on the function of the " active centres " in carbons. The active centres have been correlated with chromene groups for a series of charcoals derived from *Eucalyptus* species. These groups during normal gasification cause dissociation of the gaseous molecules into atoms which then react with the carbon.

(*k*) *Zirconium Chemistry.*—Industrial aspects of zirconium chemistry centred on exploration and development of a low-temperature and low-cost process for extracting zirconium salts of appropriate composition from the refractory mineral zircon. On the fundamental side attention was concentrated on the lower halides of zirconium. The trichloride, tribromide, and triiodide were prepared in pure state in some quantity, and the properties of these compounds in fused salt media were investigated by polarographic and cryoscopic techniques. A joint project with Professor Nyholm of University College, London, aims to study the lower halides by magnetic susceptibility measurements.

(*l*) *Graphite Investigations.*—Artificial graphite in industrial form is unsuitable for use in atomic reactors because of low apparent density. The usual method of lowering porosity and raising density in this material by repeated impregnation with hydrocarbons, followed by carbonization, has disadvantages. The viscosity of hydrocarbons, usually petroleum products, makes complete penetration of graphite slow. Also, substantial quantities of gases resulting from pyrolysis must escape. A series of gaseous carbon compounds, other than hydrocarbons, is under test to overcome these disadvantages.

Studies on corrosion of graphite by liquid metals such as bismuth were made, and the latter has little effect on graphite structure. Small amounts of metal which penetrate the latter increased the reactivity of graphite towards oxygen. Corrosion of graphite by bismuth as a nuclear reactor coolant, at high temperatures, is probably a reaction between graphite and free or chemisorbed oxygen catalysed by the metal.

Examination of the mechanism of formation of graphite compounds has revealed the existence of other new compounds of the graphite-aluminium chloride class. Investigation of these is proceeding together with examination of structural, magnetic, and electrical properties of other graphite compounds.

(*m*) *Chemical Crystallography.*—The term " metamict " is applied to minerals in which the external crystalline habit is not reflected in the internal structure. To varying degrees they are amorphous, and this is generally attributed to effects of radioactive atoms, present within the crystal, or closely associated with them in adjacent minerals of a different kind. A direct proportionality between intensity of the radioactivity and degree of crystalline disorder is seldom shown and it would seem that other factors might be involved.

In studying structure of minerals and related solid substances a new approach has been made in which order-disorder relationships in metallic oxide systems are explored. Preparation of selected phases in the TiO_2-Nb_2O_5 system and subsequent X-ray analysis of crystal structures have revealed a homologous structural sequence. At the boundaries between these phases, crystalline substances which are only partly ordered are readily prepared, and a method of analysis of diffraction data is being developed. This investigation is being extended to chemical systems closely related to the metamict niobate-tantalate series which form an important part of the general group.

The system CaO-TiO_2 is being examined and portions have been shown, with the collaboration of the Cement and Ceramics Section, to improve the hydration resistance of lime. Addition of tri-, tetra-, and quinquevalent oxides to CaO has also been studied by X-ray diffraction and several of these are of undoubted promise.

3. CEMENT AND CERAMICS.

(Cement and Ceramics Section.)

Applied projects are prominent in the programme of this Section. In addition to work on production and utilization of cement and concrete, which is subsidized by the Cement and Concrete Association of Australia, financial support has been provided by industry and by State authorities in investigations on manufacture and use of refractories, and effects of brown coal ash and slag on boiler furnaces.

(*a*) *Cements.*—A rapid analytical method for use as a control in cement manufacture has been developed to the stage of plant trials. Average time of analysis of kiln feed, or clinker product, has been reduced to one hour, with an accuracy of from 0.1 to 0.2 per cent. for each component.

Increasing the sulphate content of cement is being studied to examine the suggestion that the Australian specification limit for this component might, without detriment, be raised to conform to the higher levels permitted in other countries. Some Australian cements are improved at higher sulphate levels, and no deleterious effect has been found unless the overseas limit for sulphate content is grossly exceeded.

Premature stiffening or " false set " of cements has been further investigated. The modern trend towards higher concrete strengths automatically implies lower water requirements, and it is therefore essential that cements should show little or no tendency to stiffen during transport from the mixer to the point of emplacement. Although control over " false set " can be gained by adjusting the amount and state of hydration of the gypsum added to cement during manufacture, a more effective method of control is now apparent, in which cements are conditioned by exposure to acid gases during the milling and storage phases of production.

(*b*) *Concretes.*—Study of the mechanism of shrinkage of cement paste, mortar, and concrete has been completed. Paste shrinks in three distinct stages, correlated with the loss of capillary water, gel water, and " non-evaporable " water. At room temperature the first two stages of shrinkage are observed when water is lost during desiccation, and the third stage occurs when " non-evaporable " water in the set cement is chemically displaced by atmospheric carbon dioxide. Carbonation shrinkage is a form of drying shrinkage, the shrinkage per unit loss of water being of the same order of magnitude in the two cases.

A method has been devised for enhancing the bond strength between reinforcing rods and surrounding concrete. The reinforcement is coated with a film of an epoxy resin before pouring, and conditions so arranged hat the resin film hardens at about the same rate as the concrete. In a variation of the technique, steel rods are coated with a resin film, dipped in sand, and then heat-cured before use as reinforcement. Both techniques appear capable of increasing the bond strength by a factor of four or five measured in terms of the force required to pull a rod out of a standard concrete. Prestressed beams made with high tensile strength steel wire, coated by the resin and sand technique, failed in flexure only when the compressive strength of the concrete in the upper section of the beam was exceeded. The same type of beam, made with uncoated wires, failed by tension cracking at the under surface, at about half the load.

(*c*) *Refractories.*—Mechanical factors have been studied in failure of rotary kiln refractory linings. As kiln flexure draws attention to the strength of refractory bricks, techniques have been studied for promoting recrystallization of such brick components as magnesium oxide during firing, to attain higher density in the finished product.

Bauxite and sillimanite refractories from local raw materials, developed in collaboration with an Australian firm, have been brought to commercial production. The sillimanite products exhibited good characteristics in tests as rocket launching pads. Silica brick production is also being investigated, and a new source material has been located near Adelaide.

Some improvements were made in high-temperature strength and thermal shock characteristics of cermets based on alumina and chromium. Since dies fabricated from a titanium carbide-nickel cermet have given satisfactory service, the investigation has been extended to cover the production of dies from silicon carbide, and molybdenum disilicide-metal oxide systems. Further development of the " reaction-pressing " technique for the preparation of composite systems is leading to materials of potential value as a base for high-integrity fuel elements in gas-cooled nuclear reactors.

(*d*) *Brown Coal Ash.*—A survey is being made of distribution and composition of ash components of brown coals throughout the Yallourn field. The survey is based on a series of 500 analyses performed with the aid of the rapid analytical method developed for cement plant control. This is the first basic information available on ash variation throughout the deposit.

From the survey data, mean and extreme ash compositions are calculated, and the relevant ranges in multi-component phase systems defined for phase-equilibrium studies. From these it may be possible to characterize certain low-temperature eutectic regions responsible for the sintering and slagging effects encountered in boiler furnaces fed with brown coal.

(*e*) *Clay and Ceramic Investigations.*—Basic studies have continued on montmorillonites, vermiculites, and halloysites. Optical effects associated with diffusion of water into vermiculite sheets have been a source of new data on the kinetics of diffusion of ions in layer structures. A project introducing salt-intercalation in relation to the halloysite structure has been completed.

Problems in manufacture of ceramic ware have been investigated in collaboration with Australian firms. Typical problems have concerned: dispersion of hard kaolins, effect of clay milling on plasticity and dry strength, bentonite additions for increasing workability, non-felspathic fluxing agents in whiteware, firing faults in electrical porcelain manufacture, spalling during firing of tableware and sanitary ware, crazing in wall tile and sanitary glazes, bubble formation in glazes, and the decoration of glazes.

At the Adelaide laboratory, a study has been completed of shales from the Adelaide area, destined for brick manufacture in a tunnel-kiln plant. Investigation on clays from the Whyalla district showed that these were suitable for brick production by tunnel-kiln methods.

4. FOUNDRY SANDS.

(Chemical Research Laboratories.)

A laboratory, located in the Metallurgy Department of the Royal Melbourne Technical College, is equipped to study foundry problems with special reference to moulding sands. The Section investigates new sources of moulding materials and maintains a catalogue of Australian moulding sands. Recently, attention has been given to sands from the Melbourne area.

The Section has continued work on Australian clays used as binders in moulding sands. Bentonite from Marchagee, Western Australia, has been altered by treatment with various salts and the effect on sand properties has been studied. Properties of bentonites from New South Wales have been determined; a number of these show promise as binders for synthetic sands in Australian foundries.

Work has continued on defects caused by sand expanding, cracking, and leaving unsound patches on the casting. The validity of the crust separation test, designed by the Section to simulate mould conditions, has been demonstrated by casting tests. The equipment has now been redesigned in a compact form suitable not only for research but for foundry control tests to determine whether expansion defects are probable. In studies of the mechanism of expansion defects emphasis has been thrown on the moist layer between the expanding crust and the main body of sand. The temperature of the crust has been measured by thermocouples, and temperatures at which cracking occurs are considerable below the α-β quartz inversion temperature considered significant by previous workers.

Assistance to industry continues and advice has been given on scores of foundry problems. Two interesting investigations were concerned with granulating tin to specially low bulk density and recovery of solder in can manufacture.

5. PHYSICAL CHEMISTRY.

(Division of Physical Chemistry.)

Current research in the Division of Physical Chemistry includes conservation of water in reservoirs and dams, control of bushfires, nucleation of clouds, thermodynamics of liquid mixtures, chemical effects of high pressures, and application of physico-chemical methods to problems of reaction mechanism and energetics in biochemistry. Work has now terminated on ion-exchange techniques for separating uranium from its ores, and on the chemistry of carbon blacks in relation to the vulcanization of rubber. A major new project is synthesis of organic polymers which behave as semiconductors.

(*a*) *Water Conservation.*—Conservation of water reservoirs and dams depends upon limiting losses caused by evaporation and seepage through the soil. Effort has been concentrated on evaporation control, no work being done on methods of preventing seepage.

A new method is undergoing field trials for spreading cetyl alcohol on the surface of water, which is intended to supersede the " solvent process " in the treatment of large reservoirs. The cetyl alcohol is dispersed directly on the water surface as a fine powder, from a portable dispensing unit which in the present trials is mounted on a small boat. The surface is retreated when necessary.

Studies of compression of monolayers by wind, and of damping of waves by monolayers, have been completed. Phase changes have also been investigated which occur when mixtures containing cetyl alcohol are heated and cooled.

A new method of estimating seepage losses, based on loss of chloride ion, has been applied to an experimental water storage at Ouyen. This is a 500,000 gal. reservoir, constructed by the State Rivers and Water Supply Commission, and lined with "Polythene" sheet by I.C.I.A.N.Z. Limited.

(*b*) *Bushfire Research*.—This research on methods of fire prevention and control is carried out in co-operation with other organizations. Current studies include fireproofing of natural fuels (bark, leaf, &c.) and chemical methods of flame extinction. Investigation of tree-felling by surface explosives has led to the adoption of this method in fire-fighting practice. Skin-cream and goggles have been further developed for the fire-fighter, again with some acceptance in the field.

Data collected at several bushfires during the year have been invaluable in orienting laboratory studies, and in assessment of new types of equipment. The principal means of heat transfer during a bushfire is by radiation. The temperature of air feeding into flame fronts and of gases in convection columns have proved to be unexpectedly low.

(*c*) *Ice Nucleation*.—In relation to rainmaking experiments by the Division of Radiophysics the chemical composition and structure of silver iodide are being studied as affecting its nucleating properties. Although silver iodide promotes freezing of supercooled water, owing to the hydrophobic nature of its surface, it does not readily promote the growth of ice, or of a liquid phase, directly from vapour. When natural clouds are "seeded", success of the operation depends primarily on the proportion of silver iodide particles making contact with cloud droplets. Ways are being investigated in which contact may be made.

When concentrated silver iodide smoke is allowed to flocculate, aggregates so formed are more active as freezing nuclei than single particles. Hypotheses have been developed to explain this phenomenon.

When a single crystal of silver is exposed to iodine vapour, ice can be grown on it with crystals oriented by the structure of the iodized surface. The nucelation temperature and the degree of orientation depend on the thickness of silver iodide layer.

(*d*) *Fluids Research*. (i) *Properties of Liquids*.—Experimental and theoretical studies are conducted on the properties of liquids, their mixtures, and solutions, to predict behaviour in important processes such as distillation and extraction, and extend present knowledge of liquid structure.

Thermodynamic properties have been measured of liquid mixtures containing a component that is "associated" (i.e. hydrogen bonded). Heats of mixing of alcohols with benzene have been measured at 25, 35, and 45° C., and volume changes on mixing at 25° C.

Parameters in theoretical equations describing the properties of associated solutions have been evaluated from experimentally determined thermodynamic data for alcohol solutions, using an electronic computer. It has been found possible to describe free energy of mixing as a function of concentration for the binary mixtures of four alcohols with benzene, using only one pair of parameter values.

(ii) *Lurgi Brown Coal Tars*.—Investigations on hydrocarbons present in tar from Lurgi gasification plant of the Gas and Fuel Corporation of Victoria are given in the Organic Chemistry Section of this report (see Section 7 (h)).

(*e*) *High Pressure Laboratory*.—Research on high pressure phenomena conducted by the Division at the University of Sydney falls into two main categories. The first is concerned with the influence of pressure on rates of simple organic reactions in solution. High pressures accelerate the substitution reactions of benzene, because they favour the formation of the attacking positive ions. An increase in pressure also accelerates transfer of hydrogen atoms from thiols to free radical scavengers, a finding with an important bearing on the mechanism of industrial high pressure polymerization.

The second field of study is the behaviour of materials at the very high pressures and temperatures which occur during explosions. The pressures may be as great as a million atmospheres and persist for only a few millionths of a second. It has been possible to measure the electrical conductivity of water and organic liquids under these extreme conditions, and to show that they become highly ionized.

(*f*) *Carbon Chemistry*.—In investigation of reinforcement of rubber by carbon blacks, it has been shown that two main types of reaction may occur between carbon black and the elastomer:—

(i) Free radicals produced by mechanical rupture of the rubber during milling, and in dehydration brought about by quinone-like structures in carbon, react with other quinone groups, formed by opening of f-lactone rings believed to be present in the carbon. Reduction of quinones, and their formation from f-lactones, is favoured by the alkaline conditions of milling. These processes are responsible for some of the reinforcing properties of the acidic channel-type blacks. They do not occur to any extent at room temperature.

(ii) Chromene groups in alkaline furnace-type blacks polymerize with rubber, and possibly with sulphur. Reaction proceeds slowly even at room temperature, and satisfactorily accounts for set properties and scorching properties characteristic of furnace-type blacks.

Investigation of abilities of various carbon blacks to oxidize ferrous ion, to produce hydrogen peroxide when exposed to air in an acid medium, and to form a latent photographic image, has revealed the operation of at least three kinds of peroxidation mechanism. One predominates in low-temperature carbons, and is obviously related to the presence in these of relatively unstable hydroperoxide groups C-O-OH and of structures of the general type $HO-\underset{|}{C}=(CH-CH=)_n\underset{|}{C}-OH$. A second is effective in high-temperature carbons, especially in an acid medium, and involves chromenyl free radicals. A third results in formation of peroxides, probably transannular, which represent a substantial part of the total oxygen content of all carbons and are of relatively high stability.

The third mechanism is believed to play an important role in oxygen transfer to rubber during early stages of manufacture, and also during the useful life of a tyre, or other rubber product.

(*g*) *Uranium Extraction*.—Previous reports have described the jigged-bed process for recovery of uranium from slurries of its ores by continuous ion-exchange. A scaled-up unit, with an adsorption column 4 feet in diameter, has been installed at Rum Jungle, Northern Territory, by the Permutit Company Limited of London, for Territory Enterprises Proprietary Limited, and is undergoing trials.

(*h*) *Applied Bioenergetics*.—Study of carbon black and activated carbon has led to an investigation of novel semiconducting organic polymers. They resemble activated carbon in many respects, but instead of being produced by high temperature pyrolysis they are prepared at moderate temperatures by the usual synthetic methods. The synthesis of some triphenylmethane dyestuffs can be modified to yield carbonaceous polymers. Many of these are semiconductors, and as such are of potential interest as adsorbents in desalination of brackish water, and as model systems in study of biological processes involving semiconduction.

(*i*) *Enzyme Chemistry.*—To gain an understanding of the means by which enzymes in living organisms take up and evolve nitrogen, hydrogen, and oxygen, metal-organic complexes having these properties are being studied. The catalytic evolution of oxygen, in the reaction of certain 6-co-ordinate ruthenium complexes with hydrogen peroxide, resembles in several respects decomposition of hydrogen peroxide by the enzyme catalase. In the oxidation and reduction of the ruthenium catalyst major pathways appear to be via 2-electron steps. Predominance of 2-electron (rather than common 1-electron) processes in the mechanism of catalase action is explained in terms of thermodynamic, kinetic, and steric barriers.

Structures of oxidation products of cobaltous pentacyanide ion have been in part elucidated, and also the mechanism of oxygen uptake by the pentacyanide ion.

6. CHEMICAL PHYSICS.

(Division of Chemical Physics.)

Work continued on (a) protein structure, (b) chemical physics of the solid state, (c) determination of molecular structure and energetics, and (d) development of new instruments and techniques. Collaborative and service work has continued for industry, universities, and other establishments of the Organization.

Grateful acknowledgment is again made to Professor N. S. Bayliss for providing accommodation and supervision for the vacuum ultraviolet spectroscopic work and aspects of atomic absorption work.

A further $6,000 has been received from royalties on the multiple monochromator patent, making a total of $76,000 from this source.

(*a*) *Protein Structure Investigations.*—This work is described in Chapter XVI., Section 10.

(*b*) *Chemical Physics of the Solid State.*—Knowledge of the physics and chemistry of the defect solid state is important in understanding reactions involved in branches of chemical industry, particularly in metallurgy.

Theoretical work continues to explain the tendency of *F* centres in ionic crystals to coagulate and produce metallic specks.

Contrary to expectation, the Knight shift in pure crystals is affected by addition of solute impurities. A tight-binding model previously used to describe the distribution of electrons round solute atoms, is being used to calculate this variation in the Knight shift.

Investigation of the process of oxidation of liquid zinc metal has proceeded satisfactorily despite experimental problems. The oxide film appears to grow to a thickness of about 1,000Å. without completely covering the surface of the metal. Outside interest in the solenoid needle valve developed in the course of this work has been gratifying, and an improved and more rugged design has been produced.

In the field of optical absorption measurement a theory has been evolved on the hypothesis of a continuously variable refractive index of films evaporated on to solid substrates. In spite of mathematical difficulties, several observed properties of the films have been explained on this basis. A simple high-quality curve follower has been developed for speeding spectroscopic measurements on these films, and the device should have wide application. Work has continued on an improvement to commercial furnace temperature controllers. Cost of auxiliary equipment is trifling, and reduction in hunting amplitude of controllers has been as much as 50-fold. There has been industrial interest in this development.

Refinements in phosphorometric investigation of mechanisms of solid state luminescence have enabled concurrent processes to be distinguished with a resolution ten times as great as is possible with traditional phosphoroscope technique. Detail of the mechanism revealed will increase understanding of transport and storage of energy in the solid state. Influence of temperature appears to differ from supposition, and much can be expected from a survey of this parameter for a single phosphor material.

An investigation has been initiated into secondary electron emission properties of metal surfaces. Secondary emission in solids is extremely sensitive to surface contamination. The problem appears tractable both theoretically and experimentally. Results of the work should prove valuable in understanding of physical and chemical processes such as adsorption and catalysis.

(*c*) *Molecular Structure and Energetics.* (i) *Calculation of Molecular Energy Levels.*—New techniques for calculating thermochemical and spectroscopic properties of molecules have been further developed and applied to a calculation of dissociation energy of the carbon monoxide molecule. This quantity is directly related to the latent heat of sublimation of carbon, which has been the subject of long-standing controversy. Calculation provides evidence in favour of the highest value previously considered possible for the dissociation energy of carbon monoxide, and hence for the highest of several values suggested for latent heat of sublimation of carbon.

(ii) *Vibrational and Electronic Studies.*—Vibrational spectra have been studied of several *iso*thiocyanates. A complete assignment of vibrational frequencies for methyl *iso*thiocyanate has been made and for the other molecules a reassignment of bands due to the $-N=C=S$ group has been proposed.

Low-temperature, polarized spectra of simple crystals of a number of tetrahedral and octahedral cobalt (II) complexes have been studied. Such studies are important in development of crystal-field theory and yield valuable information regarding change of symmetry and perturbation of energy levels by surrounding molecules.

(iii) *Ionization Efficiency.*—Simple modification of the mass spectrometer has assisted study of probabilities of ionization by electron impact near threshold for multiply charged ions of rare gases. In contradiction of earlier work by others, but in expectation of theory, *n*-fold ionization was found to follow a threshold law of *n*th order. This has been proved for values of *n* from 1 to 4, and appears probable for values of 5 and 6. Upper states have been detected for many of these ions, and methods derived for calculating ionization potentials of these levels.

The determination of relative electronic transition probabilities has been studied, for reactions leading to ionization in the gases krypton and xenon. The threshold law for autoionization appears to be a step function of excess electron energy.

(iv) *Structure Analysis by Electron Diffraction Methods.*—Electron diffraction methods have been applied to structure analyses in clays. Clear single-crystal patterns were obtained from specimens which normally yield only limited powder patterns under X-ray examination.

More work has been carried out on montmorillonite and some of its intercalated products. For the latter intercalating molecules are not well ordered with respect to the parent lattice, while accepted structure for montmorillonite has been over-simplified.

(*d*) *Development of Specialized Instruments and Techniques.*—Development of new apparatus and techniques is a vital part of the Division's activities, and often leads to clearer understanding of physical and chemical phenomena, and to instruments capable of commercial exploitation.

(i) *Electron Microscopy.*—The first stage of the determination of the limit of resolution of the conventional electron microscope has been completed by the construction of a high-quality objective lens. The best micrographs obtained with this lens show a resolution of 7 Å.

Further progress towards the limit of 2-3 Å set by spherical aberration depends on minimizing the effects of chromatic aberration and asymmetry.

The first of the ultramicrotomes developed in the Division and manufactured by the Fairey Aviation Company of Australasia under the trade mark " SI-RO-FLEX " was exhibited at the Fourth International Conference on Electron Microscopy held in Berlin in September 1958. An improved version has since been developed in collaboration with the same company.

Difficulties encountered in the fixation of plant tissue for electron microscopic studies of cell organization and function in plants have been overcome by pretreating the material with isotonic glucose prior to fixation. This eliminates swelling of those cell components enclosed by membranes.

(ii) *Mass Spectroscopy.*—A major undertaking, building a large mass spectrometer, has been completed and difficulties of fabricating a large vacuum system in an intractable alloy have been overcome.

A vacuum monochromator for the extreme ultraviolet, to be used in conjunction with the new mass spectrometer in studies of photoionization, has been almost completed.

An ionization source incorporating a spherical velocity analyser for electrons has been designed and built. Use has been made of sapphire and ruby balls to obtain precise alignment and insulation of component parts.

The ionization source for the existing mass spectrometer was completely rebuilt, using sapphire balls as insulators. This has reduced the difficulties of cleaning the source, which in the previous design were almost insuperable.

Ionic plasmas confined by magnetic fields are being studied. Magnetic fields can be used satisfactorily to concentrate electrical discharges in gases, and radiation sources for the extreme ultraviolet have been built incorporating magnetic collimation in various rays.

(iii) *Atomic Absorption Spectroscopy.*—During the past few years the Division has pioneered the development of methods of chemical analysis based on atomic absorption spectroscopy. This work was initiated in 1953 when theoretical studies indicated that methods based on atomic absorption spectra would offer advantages over conventional methods using emission spectra. The new method developed entirely in the Division has been vindicated by overseas work and has now been accepted as a powerful analytical technique. One English manufacturer is producing atomic absorption equipment under licence from C.S.I.R.O. and other firms in England and the United States of America should commence production soon. The method has proved valuable in the analysis of soils and plants, and is widely used by the Division of Plant Industry.

Until recently the atomic absorption method has been applied only to the analysis of solutions, but recent work has demonstrated that the method is applicable to the direct analysis of metals and alloys. This aspect is now being pursued since it opens up new fields of application.

An atomic absorption method has been developed for rapid determination of calcium and magnesium in blood. Unlike other methods, the new technique does not need preliminary ashing or precipitation, and requires only 0.2. ml. of serum for determination of both elements. Simple equipment is being developed for such analyses and this should serve as a prototype for commercial production.

An instrument has been constructed for determination of small amounts of sodium in plants. The instrument, known as " SI-RO-SPEC ", is of extreme simplicity, and has enabled the Botany Department, University of Adelaide, to carry out analyses which were hitherto impossible.

Numerous enquiries have been received from industrial and research laboratories throughout Australia regarding applications of the atomic absorption method. Specialized items of equipment, not yet available commercially, are loaned to those laboratories carrying out their own atomic absorption measurements. It is hoped that in the near future apparatus for atomic absorption measurements will be manufactured commercially in Australia.

(iv) *Development of Specialized Optical Instruments and Techniques.*—A simple double-beam attachment for use with vacuum ultraviolet monochromators is being designed and constructed to permit direct recordings of transmittance over the range 1,500-6,000 Å.

A new method of measuring wavelengths in echelle spectra has been developed and applied in analysis of rotational structure in the second positive system of nitrogen. A method is under test for automatically compensating in echelle spectra for shifts due to temperature fluctuations.

(v) *X-Ray Diffraction.*—Operation of the high-power X-ray generator has been further improved and methods developed for the adjustment of X-ray foci and goniometers.

A method, involving an internal standard, has been devised for the determination of precise cell dimensions.

The device for the measurement of identity periods has been elaborated to permit operation in the equi-inclination mode at higher angles to increase accuracy of measurement.

(vi) *Electron Diffraction.*—Work has continued on problems associated with the electron-optical imaging of crystal lattices. Production of fringes associated with the crystal lattice has become a commonplace of commercial electron microscopes, and considerable direct and immediate application exists. Elucidation of the complicated and varied images from the clay mineral antigorite is an example. These have been shown to be due to dynamic scattering of novel type, for instance, from simultaneous dynamic scattering of a fundamental lattice reflection and kinematic scattering of the superlattice reflection. From this it is clear that intuitive evaluations of high resolution micrographs should be avoided.

Further problems investigated include the effects of dynamic scattering on the moire-like fringes obtained in electron micrographs of superimposed crystals, and the nature of the simplest fringe patterns obtained, for instance, from the phthalocyanines under practical conditions of restricted aperture, defect of focus, and finite source.

Further confirmation has been obtained that one type of fringe pattern, basically the simplest obtained by conventional electron microscopy, may be directly interpreted in detail as a simple Fourier image phenomenon. Development of this idea led to the discovery that under restrictive conditions electron micrographs should be interpreted in terms of charge distribution in the crystal, rather than potential distribution as conventionally assumed.

By the nature of the methods employed, a parallel study was made of the various diffraction patterns associated with these effects, and results related to microscopy are being employed in techniques of dynamic theory of structure analysis at present under development.

(*e*) *Collaborative and Service Work.*—Specialized facilities have been made available to industry, universities, and other establishments of the Organization. The following are a selection of the more important problems undertaken.

(i) *Electron Microscopy.*—Examination of tungsten carbide tool tips; particle size measurements of colloidal silver.

(ii) *Mass Spectroscopy.*—Examination of natural gases for presence of helium; analysis of fuel gases.

(iii) *Spectroscopy.*—Infra-red determination of water ontent of sugars; infra-red spectra of quinolones and cridones; infra-red analysis of hydrocarbon fractions.

Atomic absorption spectroscopic determination of lkali and alkali earth metals in sugar cane ash; determination of magnesium displaced by strontium from vermiculite crystals.

(iv) *X-ray Diffraction.*—Characterization of C_{27}-phthienoic acid and ester samples and of oxidation products of phthienoic acid; examination of sinter.

(*f*) *Instrument Laboratory.*—Major items completed nclude: specialized light sources for spectroscopy, stabiized modulated hollow-cathode lamp power supplies, constant current power supplies, ion sources for mass spectroscopy, apparatus for secondary emission measurements, wave-front shearing interferometer, spectrometer for sodium determination, and a new type of countercurrent solvent extraction apparatus. Progress has been made in construction of a diffraction grating ruling engine for production of plane and concave gratings.

7. ORGANIC CHEMISTRY.

(Organic Chemistry Section.)

Activities continued along the lines of the previous year. Special effort has been made in the application of modern techniques to certain problems and these have quickly proved their value. In examination of phenolic materials in tars from the Lurgi process from brown coal, gas chromatography made possible the identification and estimation semi-quantitatively of almost all phenols present as far as the C_9 family. Gas chromatography is also proving its value in a full analysis of cane wax. Although nuclear magnetic resonance equipment is not yet available, help was obtained from overseas and in this way the structure of a new alkaloid in the Western Australian blue lupin has been established. X-ray analysis was of unique value where degradative structural work on organic compounds has proved either slow or inapplicable, as in examination of lanosterol and cryptopleurine. An X-ray spectrographer has now been appointed and seconded to the Division of Chemical Physics to do structural work in this manner.

As the staff of the C.S.I.R.O. and Melbourne University Microanalytical Chemical Laboratory gains experience it is dealing with an increasing number of analyses. This year, with no increase in staff, analyses performed rose from 6,600 to 7,800. The universities and C.S.I.R.O. provide, approximately equally, 80 per cent. of the requests. One-quarter of the university requests are from overseas. Mrs. E. Tong, a graduate from the University of Malaya, was a guest worker, studying with a view to setting up a microanalytical laboratory at Singapore.

Investigation of alkaloids of Australian plants continues in the university and other Australian research organizations. Most of these materials, through collaboration with the Smith, Kline, and French laboratories, are screened physiologically. Large-scale isolation of the alkaloids needed for these tests is done in the Section's large extraction equipment.

(*a*) *Fleece Components.*—This work on wool wax and the acids of suint is described in Chapter XVI., Section 4.

(*b*) *Sugar Cane Wax.*—Crude waxes from Australian mills and one from a mill in India were shown to refine and bleach easily by the solvent refining process developed in the Section.

Work on sugar cane wax here has been done with only superficial knowledge of its composition. Analyses of the wax abroad have been only partially complete but indicate that it may have an unusual composition. After suitable chemical modification its analysis in detail should be possible by gas chromatographic methods. This analysis should explain why sugar cane wax and chemical modifications of it so far made have failed to produce a complete rival to existing best hard waxes.

(*c*) *Plant Alkaloids.*—Pharmacological screening of plant alkaloids and other constituents in collaboration with Smith, Kline, and French Laboratories has continued and results are available for 30 species. Close liaison has been maintained with university chemists participating in the programme. Most species examined show little or no useful activity, but several warranted further examination, and this is in progress. One species investigated chemically elsewhere is undergoing detailed physiological testing for possible commercial production. Further alkaloid extracts have been submitted for anti-tumour testing to the United States Cancer Chemotherapy National Service Centre, and a number of pure alkaloids have been tested for anthelmintic activity.

Alkaloids in *Lunasia quercifolia, Cryptocarya pleurosperma,* and *Kopsia longiflora* are also being studied and progress has been made with the structural problems involved.

(*d*) *Stock Poisons.*—Work has continued with the liver-damaging plants. The major alkaloid of *Crotalaria goreensis* was shown to be 7-hydroxyl-1-methylenepyrrolizidine and not 7-hydroxy-1-methyl-1, 2-dehydropyrrolizidine as reported previously. A diastereoisomer of this structure is present as a minor component. The highly toxic constituent of *Crotalaria lanceolata* is probably an alkaloid, and the present objective is the isolation of the pure alkaloids.

Studies of *Heliotropium supinum* have been completed with identification of the third major base as echinatine, the viridifloric ester of heliotridine. Minor constituents isolated were the trachelanthic and viridifloric esters of 7-angelylheliotridine, while the *N*-oxide of 7-angelylheliotridine was isolated but may be an artefact. Identification of the latter directed attention to the unexpected hydrolysis which these pyrrolizidine alkaloids suffer under mild conditions. Alkaloids such as lasiocarpine which are esters of β-hydroxy or $\alpha\beta$-unsaturated acids are rapidly hydrolysed by cold dilute sodium hydroxide above pH 9, and the *N*-oxides of these alkaloids are even more unstable in alkali.

Work continues on alkaloids of the Western Australian blue lupin. Structure of the new alkaloid found in the seeds has now been established by nuclear magnetic resonance spectral studies as (-) Δ^2-dehydro-4-oxo-sparteine. Fresh tops of lupins differ from the seeds in alkaloid content. However, recent evidence suggests that alkaloids are not responsible for stock losses on pastures containing the blue lupin and interest now centres on the dry husks left after the plant dies.

(*e*) *Other Biologically Active Plant Constituents.*—A grant from the United States Population Council Inc. made possible extension of biological-chemical studies to plants allegedly used in the western Pacific area for fertility control. This programme is undertaken in collaboration with the Sheep Biology Laboratory of the Division of Animal Health and Production. Inquiries have been made from anthropologists and others in a position to provide information.

In addition to extracts of alkaloid-containing plants, those from other species have been submitted both to the Victorian Cancer Institute Board and to the United States Cancer Chemotherapy National Service Centre for anti-tumour testing. Some plant extracts are also being tested for anthelmintic activity.

(*f*) *Chemistry of Root Exudates.*—*Backhousia angustifolia* leaves contain angustione or dehydroangustione which inhibit germination of hoop pine in laboratory experiments. It has been shown, in collaboration with officers of the Division of Plant Industry, that these substances are not effective as germination inhibitors under field conditions. The failure of hoop pine to regenerate in the vicinity of *B. angustifolia* is not primarily due to the presence of these germination inhibitors in *Backhousia* litter. Two series of field tests have been completed, and analyses of *Backhousia* leaves and litter are in the final stages.

The literature has been reviewed on the influence of legume root exudates upon the course of nodulation with *Rhizobium*. An alternative interpretation of existing data has been advanced and it has been suggested that this influence is affected by surroundings, preplanting history, and nitrogenous impurities present in some samples of agar. In collaboration with officers of the Division of Plant Industry this alternative is being tested, using subterranean clover as both the donor plant and test species.

(*g*) *Fats and Related Long-chain Compounds.* (i) *Insecticides*.—It was previously reported that in an attempt to prepare synthetic analogues of potent naturally occurring insecticides, the *iso*butylamides of all four possible 2,4-hexadecadienoic acids had been made and submitted for evaluation. All had negligible insecticidal activity, confirming that, to possess high insecticidal activity, these unsaturated amides probably needed additional unsaturated centres not conjugated with the dienoic unit. The terpene aldehyde citral presents the opportunity to prepare simply the amide of a dienoic acid containing an additional olefinic centre separated from the main diene unsaturation. One of the *iso*butylamides prepared in this way has shown weak activity against houseflies (see Chapter XI., Section 16).

(ii) *Derivatives of Oleic Acid*.—The attempt has continued to convert oleic acid to chemicals with new fields of use. Esters of derived 2-hydroxy-2-octylsebacic acid have proved as attractive as phthalates for use as plasticizers, but less efficient than esters of unsubstituted sebacic acid. As lubricants they proved too unstable. On the other hand, 2-octylsebacic acid was also prepared and its octyl ester has the required mobility at low temperatures and the necessary stability at high temperatures to fit it as a lubricant if economically competitive.

(iii) *Naturally Occurring Acetylenic Acids*.—Ximenynic acid with " enyne " unsaturation has been found in members of two genera of the order Santalales. To study its distribution in other genera, fruits of two species of the genus *Exocarpus* were examined. It formed 60 per cent. of the seed fats of these species. Examination of fat from the roots of *Exocarpus cupressiformis* (the native cherry) revealed the presence of a still more unsaturated acid, an unstable crystalline octadecendiynoic acid. Members of the order Santalales appear a rich source of these inaccessible materials.

(*h*) *Brown Coal Tar*.—A description of the use of gas chromatographic methods for the analysis of mixtures of phenols has been published. Twenty different materials were tested as the stationary liquid phase in an investigation of phenols from the Lurgi gasification plant of the Gas and Fuel Corporation of Victoria. Successive use of polar and non-polar liquid phases was needed to resolve even moderately complex mixtures of phenols. The most effective of the twenty liquids were used to analyse the tar acids present in the lower-boiling fractions which constitute 65 per cent. of Lurgi tar. Gas chromatographic analysis applies with certainty only to the major constitutents of the tar acids, but more detailed analysis is very seldom needed and the speed of the method makes it of great value.

Parallel with this work, the Division of Physical Chemistry is investigating the hydrocarbons in tars from the Lurgi plant, and has completed work on the fraction boiling from 30 to 130° C. Aromatic hydrocarbons, in particular benzene and toluene, are the major constituents (83 per cent.), while the remainder are largely straight-chain compounds: 1-olefins (11.5 per cent.) and *n*-paraffins (5.5 per cent.). Fifty-seven hydrocarbons were present in the 30-130 fraction: 6 aromatics, 33 olefins, and 18 paraffins. Twenty-four of these, accounting for 95 per cent. of the fraction, were identified.

(i) *Components of Tubercle Wax*.—Methods employed for examination of carnauba and wool waxes have been applied to fractions of human tubercle wax made available through the gift of a large quantity of killed bacillus from the Commonwealth Serum Laboratories. The following normal chain acids have been isolated in pure condition from the acetone-soluble wax: palmitic, stearic, oleic, and hexacosanic; and the branched chain acids; tuberculostearic, and the C_{27} and C_{25} phthienoic acids. A quantitative method of estimation has been devised in which the acids are reduced to the hydrocarbon before gas chromatographic resolution. This method makes examination of components of higher molecular weight possible. In another method in which gas chromatography has been coupled with oxidative degradation, the structure of the C_{27} phthienoic acid has been confirmed as 2,4,6-trimethyltetracos-2-enoic acid and that of the C_{25} phthienoic acid established as 2,4,6-trimethyldocos-2-enoic acid.

8. CHEMICAL ENGINEERING.

(Chemical Engineering Section.)

The reorganization of the Section into three independent Research Groups, viz. the Process Development Group, the Unit Operations Group, and the Fundamental Group, together with a General Services Group, has now been completed. Six new Research and Experimental Officers have been recruited.

Work has been completed on the first phase of the brown coal hydrogenation project and assembly of equipment has started for the second phase, employing a much longer countercurrent flow reactor. The ilmenite-rutile project has also been completed and a start made on a new project on recovery of tin from its ores by volatilization as sulphide.

Programmes of the new Unit Operations and Fundamental Groups are not yet fully effective, although work on kinetics of gas reactions with carbon has been transferred to the latter group, and building has commenced of equipment for study of the hydrodynamics of liquid-liquid systems. The Unit Operations Group has started theoretical and experimental investigations of large-scale water desalination, particularly the combination of a multi-stage water distillation plant with a nuclear power station. A project on mixing non-Newtonian liquids, with particular reference to dough mixing, has been started and plans made for study of comminution theory and of classification by hydraulic cyclones.

(*a*) *Utilization of Brown Coal*.—This work is described in Chapter XIX., Section 5.

(*b*) *General Process Development.* (i) *Rutile from Ilmenite*.—Investigation was continued of a new process for production of granular rutile from ilmenite by sulphidization followed by oxidation and hydrolysis of iron sulphides in an autoclave, further support being received from a group of Australian companies.

The influence has been studied of process variables on the performance of the second stage of the process. Problems were examined in the separation of iron hydroxide sludge and elemental sulphur and also of the final clean-up of the product rutile.

Technical information obtained has been used to produce an overall process flowsheet and make an economic appraisal.

(ii) *Recovery of Tin.*—Recovery of fine-grained cassiterite not amenable to gravity concentration is a problem in the treatement of a number of Australian tin ores. The possibility is being investigated of obtaining increased recovery from such ores by volatilization of the tin as sulphide at high temperature. Experiments are being performed in a small fluidized bed reactor, using ore from Renison Bell, Tasmania, which, being predominantly sulphidic in nature, should be particularly suitable for the process. Early results are encouraging and closer examination of reaction conditions is proceeding.

(*c*) *Gas-solids Contacting in Fluidized Beds.*—Accurate prediction of performance of fluidized bed reactors is not possible at present owing to inadequate knowledge of the efficiency of contacting between solid particles and gas passing through the bed as bubbles.

A technique has been devised for selectively sampling gas contained in bubbles. Experiments using this technique, together with special surveys of gas distribution in the bed as a whole, disclosed rapid exchange of gas between bubbles and continuous phase. The mechanism of this exchange of gas and the distribution of gas flow in fluidized beds are being determined.

(*d*) *Hydrodynamics of Liquid-Liquid Systems.*—The hydrodynamical behaviour of liquid-liquid systems is being studied with particular reference to mass transfer. A horizontal flow channel has been constructed with provision for measuring velocity, temperature, and concentration distributions across the interfacial region. Attention is also being given to measurement of the scale and intensity of turbulence.

(*e*) *Mixing of Non-Newtonian Liquids.*—Mixing of high-viscosity doughs such as rubber and thermoplastic compositions, and baker's dough, is practised on a large scale in processing and food industries, but selection and design of suitable equipment for these purposes is still empirical. Survey of literature has confirmed that little fundamental information is available, so simplified models are being developed of various mixing processes to determine their efficiency and power consumption.

(*f*) *Desalination of Water.*—A promising method for large-scale water desalination is distillation in a multi-stage evaporator of conventional or flash type, using a nuclear reactor for heat. With the addition of power generation equipment, part of the load could be interchanged between power and water production according to the power demand, enabling the reactor to be operated at a high load factor, and capital charges to be minimized.

Efficiency of this method is limited at present by scale deposition in the evaporator at temperatures above 95-100° C. To overcome this difficulty, a spray evaporation principle is being investigated. Equipment is under construction for long-term scaling tests. Sea-water will be transported to the site in tank wagons.

(*g*) *Process Equipment Laboratory.*—This Laboratory provides chemical processing equipment for use by Government Departments and private firms, and fulfils the requirements of the Laboratories as a whole. During the year the Laboratory handled six projects for other Sections or Divisions of the Laboratories and other Government Departments, and seventeen projects for industry, the latter using staff provided by the companies themselves.

The following major projects were also undertaken:—

(i) *Extraction of Sugar Cane Wax.*—A prototype plant for the extraction of sugar cane wax has been built and tested in a Queensland sugar mill. Work has also been undertaken on refining of the wax.

(ii) *Dyeing of Wool.*—Assistance is being given to the Division of Protein Chemistry developing of a new process devised for rapid dyeing of wool tops using the dye in formic acid solution. A unit for continuous dyeing of wool by this method is under construction, and the most suitable method is being determined for reconcentration of dilute formic acid recovered from the process.

(iii) *Dissolution of Gypsum in Irrigation Water.*—Assistance is being given to the Division of Plant Industry (Regional Pastoral Laboratory, Deniliquin) to develop a single-pass portable machine for continuous dissolution of calcium sulphate, obtained from local deposits of gypsum, in irrigation water. The final concentration desired is one-half of the saturation value.

(iv) *Solar Energy.*—Work has continued on utilization of solar energy and the commercial drying of grapes and peanuts has been studied.

XVIII. MINERAGRAPHY AND ORE-DRESSING.

1. General.

Mining is one of Australia's major fields of industry, and makes a substantial contribution to the nation's export income. The Organization and its predecessors have recognized the need to establish research facilities for the full exploitation of Australia's mineral resources. The techniques necessary for mineragraphic research are highly specialized and require considerable experience, and only the largest operating mines are able to provide these facilities for their own use. The Organization maintains the Mineragraphic Investigations Section in Melbourne and Ore-dressing Laboratories in Melbourne and Kalgoorlie to carry out research on the composition and treatment of ores, both as basic research and at the specific request of establishments concerned with mining production.

The current work of the Mineragraphic Investigations Section is described in Section 2 of this Chapter.

The Ore-dressing Laboratories are operated in Melbourne in collaboration with the University Department of Mining, and in Kalgoorlie in cooperation with the School of Mines. These Laboratories provide complementary research facilities to the Mineragraphic Investigations Section, and investigate the composition of ores and provide advice on methods for their full-scale treatment. This work is reported in Sections 3 and 4 of this Chapter.

Work on the utilization of minerals is carried out by the Division of Mineral Chemistry (see Chapter XVII., Section 2).

Research on the composition and treatment of Australia's black and brown coal deposits is described in Chapter XIX.

Mineragraphic Investigations Section.—No major change was made during the year in the research programme of the Section. Forty investigations were made of mineral associations in ores, rocks, drill cores, and mill products submited by mining companies, the Ore-dressing Laboratory, Melbourne, and the Chemical Research Laboratories.

Dr. F. L. Stillwell continued to work in the Section. Mr. I. M. Threadgold has been awarded a teaching assistantship at the University of Wisconsin and will undertake post-graduate research at that university.

The work of the Section has been facilitated by contributions from a number of mining companies through the Australasian Institute of Mining and Metallurgy. The University of Melbourne has cooperated in providing laboratory accommodation and library facilities.

Ore-dressing Laboratory, Melbourne.—Cooperative investigations undertaken for mining companies continue to form a substantial part of the work of the laboratory. These investigations have resulted in substantial donations, forming a fund from which the salaries of three members of staff are currently derived. In addition, for one investigation, the sponsor reimburses the Section for the full-time services of an Experimental Officer.

The general work of the laboratory continues to cover a wide field. Beach sands and ores of iron, manganese, nickel, copper, lead, uranium, and gold were investigated during the current year, during which nineteen reports were issued.

Ore-dressing Laboratory, Kalgoorlie.—Eight reports of investigations and 282 certificates were issued during the year. Six reports had reference to gold ores, one to an ilmenite sand, and one to a sillimanite ore. As in previous years a number of certificates recorded assays made for the Government Geologist. In addition many assays were done for prospectors and for banks.

2. MINERAGRAPHIC INVESTIGATIONS.

(Mineragraphic Investigations Section.)

Ore from the deeper levels of the Peko mine, Tennant Creek (N.T.) showed a similar mineral association to the primary ore at 400 ft. level. The proportion of pyrrhotite increased with depth, and the copper minerals tended to be more dispersed. The flotation tailings of the mine were examined to determine the nature of the gold losses. Gold in drill cores of the Orlando prospect, Tennant Creek, was found to be associated with bismuthinite, and copper minerals, as in other occurrences in the Tennant Creek field.

Spectrographic analyses of gold from several Victorian gold mines were made to discover the associations of trace elements with the gold in the several mines, and an auriferous sulphide flotation concentrate from Gold Mines of Australia, Kalgoorlie (W.A.), was studied to determine the degree of overgrinding to which the mill feed had been subjected.

The rare uranium mineral, boltwoodite, was identified from the Pandanus Creek prospect (N.T.), and a large number of secondary uranium minerals was identified in El Sharana ore (N.T.). A petrological study was made of rocks from the Mary Kathleen (Qld.) mine area.

Further studies were made of oolitic iron formations in drill cores from Constance Range (Qld.) and Roper Bar (N.T.), and of specimens of iron ore from the Bungalbin Range (W.A.).

A tin smelter slag from Irvinebank (Qld.) was found to contain tin as unreduced cassiterite, metallic tin, and tin sulphides, and as tin dissolved in the slag glass; tin in the ore of the Gilmore mine (Qld.) was found to occur as fine-grained cassiterite, and locally as stannite.

Impurities in glass sands were determined, and beach sands containing valuable heavy minerals were examined from Norman Creek (Qld.) and Arnhem Land (N.T.).

Red and yellow "flake" pellets, formed during the production of battery lead oxide, were found to consist variously of alternating concentric growths of litharge (α-PbO), massicot (β-PbO), and minimum (Pb_3O_4), around cores of metallic lead and of a variety of foreign particles (rock, minerals, slag) introduced with the lead. The texture of the flake indicated that various factors such as temperature and oxygen supply within the Barton pot varied during production.

Studies of the minerals in the Broken Hill lode, and of the rocks in the district were continued, with particular attention to the "banded aplites". Lead ores at Magnet (Tas.) and Lawn Hills (Qld.) were also examined.

Examination of the silt and fine sand fractions of some Victorian soils revealed that the majority of the opaline bodies previously described from them as sponge spicules were, in fact, phytoliths—opaline silica bodies shed from grasses and other plants. They constituted 1-2 per cent. of the soils examined, and indicated the existence of a "silica cycle" of the order of 1,000 years in soils. The shapes of the individual phytoliths related to the individual plants secreting silica, so that phytolith assemblages varied with locality and plant populations. Fossil opal phytoliths have been found in Tertiary and Quaternary sediments, and proved that phytoliths were formed in plants of earlier times.

Further studies, in association with officers of the Division of Plant Industry and of the School of Agriculture, University of Melbourne, indicated that the phytolith content of pasture grasses was the chief cause of wear in sheep's teeth, and that undue wear was caused by harsh phytolith-rich grasses. A large proportion of the phytoliths were discharged by the animal in faeces, but commonly in a crushed condition.

3. ORE-DRESSING INVESTIGATIONS.

(Melbourne Laboratory.)

Work on beach sands was confined mostly to the ilmenite-bearing sands in the south-west of Western Australia. Reports issued dealt comprehensively with recovery of ilmenite and leucoxene and gave preliminary data on recovery processes for zircon and monazite.

Two reports were issued on oolitic iron ore, one relating to Roper Bar, Northern Territory, and one to deposits at Constance Range, Queensland. These ores are not readily amenable to concentration, but a moderate amount of beneficiation can be achieved under carefully controlled conditions.

Investigations continued of the flotation treatment of base metal ores from Rum Jungle. Some of the depressants which benefit flotation affect principally the silicate content of the concentrate while others partially depress the pyrite and still others depress the graphite content. Nevertheless, attempts to achieve an overall improvement by using two depressants in combination have not proved successful.

For several uranium ores concentration appears likely to have only limited success, because part of the uranium is very intimately associated with the host rocks. On the other hand, for two uraninite ores investigated, flotation was fairly successful, two-thirds to three-quarters of the uranium being recovered in about a fifth of the weight. Preliminary flotation tests on a secondary uranium ore containing carnotite and saleeite were not promising.

From the results of investigations on further aspects of the proposed expansion programme at Wattle Gully, it has been estimated that modernization of the treatment process and equipment will lead to reduced operating costs and the capital outlay will probably be recouped within about three years.

There have been a few investigations of an unusual type. Fibre content and fibre length distributions were determined for some samples of asbestos ore. The suitability was investigated of a highly magnetic by-product from beach sands as heavy medium for coal cleaning. A fly-ash from a boiler plant was also investigated. This represented a substantial loss of combustibles, but it was shown that by a simple flotation process it could be upgraded from 25 per cent. carbon to 60 per cent. carbon with over 90 per cent. recovery.

4. ORE-DRESSING INVESTIGATIONS.

(Kalgoorlie Laboratory.)

Concentration and magnetic separation tests were made on a heavy mineral sand from near Capel, Western Australia. Ilmenite concentrates were produced containing more than 60 per cent. titanium dioxide. Prospecting was in progress in the area at the time when the tests were made and consideration was being given to further development of the area.

Beneficiation tests were made on a sillimanite ore from Mount Ragged via Esperance, Western Australia. The sillimanite occurred as sheaves or bunches of fine needles in quartz, and a marketable grade of sillimanite concentrate could not be produced.

Gold recovery tests were made on a sample of battery tailings form the Haoma Gold Mine, Mount Monger, Western Australia, and 65 per cent. of the gold could be recovered by percolation leach cyanidation. Flotation recovered 75 per cent. of the gold in a low weight per cent. concentrate.

Treatment tests were made on a number of ore types following unexplained periodical rises in the gold content of plant residues from the Sons of Gwalia Mine at Gwalia, Western Australia. Some ore samples contained gold associated with sulphide minerals, and a finer grind was necessary for satisfactory recovery of gold by cyanidation.

Ore and battery treatment products were submitted from the King Solomon Gold Mines, Edward's Find, Western Australia, and 91 per cent. of gold in the ore could be extracted by amalgamation and agitation cyanidation after grinding to all minus 72 mesh (B.S.S.). Normal battery treatment with percolation cyanidation would recover from 65 to 67 per cent. of the gold in the ore. Some test work was also done on battery treatment products. Sixty-six per cent. of the gold could be recovered from a 50-50 sand-slime mixture by normal percolation cyanidation, and cyanide and lime consumptions were reasonable. Amalgamation of the strake concentrate after grinding to all minus 200 mesh would recover 71 per cent. of the gold. A further recovery of 94 per cent. of the gold in the amalgamation residue could be made by agitation cyanidation.

Pilot-plant scale grinding and flotation tests were made on flotation products from the North Kalgurli (1912) Limited treatment plant to check results obtained by batch laboratory tests made in the mine laboratory. These tests confirmed the batch work and plant procedure was modified accordingly.

XIX. FUEL.

1. General.

Coal is a variable material, and coals from different deposits must undergo careful selection and classification for application to specific uses. The more valuable types of coal must not be wasted indiscriminately, but be conserved for special purposes. It is essential therefore for Australia's coal resources to be studied in detail, so that available coals are used as effectively as possible.

The Organization's main centre for investigation on fuels is the Coal Research Section, located at North Ryde, New South Wales. This Section was established to carry out a comprehensive study, on a national basis, of the physical and chemical characteristics of Australian coals. It aims to promote the more efficient use and economic development of coal resources by increasing the efficiency of carbonization, gasification, and combustion processes; by improving the quality of metallurgical coke; by evaluation of the liquid by-products (tar, light oil, and pitch) from the carbonization of coals; by determination of the mechanical properties of coal and coke; by the application of petrography to the control of coal preparation and carbonization; and by research into the fundamental chemistry and physics of coal and coke.

The Chemical Research Laboratories are undertaking work on the engineering aspects of the gasification of low-rank coals, and this work is reported in Section 5 of this Chapter. Research on the chemistry of tar from Lurgi gasification plant is reported in Chapter XVII., Section 7 (h), and work on brown coal ash in Chapter XVII., Section 3 (d).

Cooperative investigations on the fossil pollens in brown coal are undertaken in the Botany School, of the University of Melbourne (see Section 4 of this Chapter).

Coal Research Section.—Two new permanent single-storey buildings have been completed, the larger of which is being used for pilot-plant and carbonization and combustion research, and the other is the Section's workshop.

The Officer-in-charge attended the Third International Conference on Coal Science, held at Valkenburg, Holland, in April, at which several papers from the Section were presented.

The Section's third symposium on "The Production, Properties, and Utilization of Foundry Coke" was held during the year. Those taking part included representatives of the coke manufacturers, the iron and steel industry, and the foundry industry, as well as officers of the Section. The discussions were concerned with research work being undertaken by the Section in the interests of the coke-making and foundry industries.

Generous gifts of research equipment from the Broken Hill Proprietary Co. Ltd., C.S.R. Chemicals Pty. Ltd., and the Newcastle Wallsend Coal Co. are gratefully acknowledged.

2. Coal Utilization.

(Coal Research Section.)

(*a*) *Carbonization Investigations.* (i) *Improving the Quality of Metallurgical Coke.*—Coke is one of the major cost items in the manufacture of iron and steel, and improvements in its chemical and physical properties can provide significant gains in productivity and efficiency of both foundry cupolas and blast furnaces. The Section continues research into the production of better metallurgical coke.

Work is proceeding on the coking coals of the Northern Coalfield of New South Wales. Plans for the establishment of a smelting plant for lead and zinc at Cockle Creek in the Newcastle district make the production desirable of a very strong metallurgical coke from coking coals available at nearby collieries working the Borehole, Young Wallsend, Victoria Tunnel, and Dudley seams. Despite high volatile-matter content, these coals have good coking properties, but improvement would be desirable in certain physical characteristics of the coke produced.

Young Wallsend coal was selected as typical of these coals. Pilot-scale carbonization tests were carried out, and the coke products examined by size grading, drop shatter, drum abrasion, density tests, and petrograhic techniques. The following types of test coke were produced, according to conditions of preparation and carbonization: Hard, small cokes, suitable for blast furnaces, were made by carbonizing Young Wallsend coal ground very finely, or by coking at higher temperatures, or both. Hard cokes of moderate size, suitable for metallurgical purposes, were made by blending Young Wallsend coal with lower-volatile coking coal, or with devolatilized coal, or by charging at high bulk density. Large cokes of moderate hardness, probably suitable for foundry cupolas, were produced by blending Young Wallsend coal with low-temperature, fluidized-bed char, or with finely ground low- and high-temperature chars and cokes, or with magnetite fines.

(ii) *Low-temperature Carbonization.*—For low-temperature carbonization the fluidized-bed process continues to claim world-wide attention. Applications of this technique to the carbonization of Australian coals are being investigated in a pilot plant with a nominal capacity of 50 lb. of coal per hr. The carbonizer unit is 6 in. in diameter and can be used to carbonize coal fines in the presence of either air or recycled gas, under a wide range of operating conditions. Immediate objectives include: optimum yield of the desired products, and control of dust carried over from the carbonizer to the by-products' recovery plant. The approach to the latter problem is study of the factors influencing elutriation losses from fluidized beds of char. Quantities of low-temperature char have been produced by various blending experiments. The nature and properties of the liquid by-products have also been studied.

(iii) *Evaluation of Carbonizing Properties.*—Pilot-scale carbonization tests were made on profile samples from the Donaldson seam in the Northern Coalfield of New South Wales. Utilization of coal from this seam for carbonization purposes would be difficult owing to the high sulphur content, which cannot be reduced by conventional washing processes.

Pilot-scale carbonization of coal from the Bulli seam at Nattai-Bulli Colliery, South-western Coalfield, New South Wales, produced high volumetric yields of moderately rich gas. By-products' yields were normal for a coal of this rank. The coke products were well fused, dense, and blocky, but much fissured. This coal would be well suited to the production of good-quality metallurgical coke.

Study continues on the carbonizing properties of Queensland coals. Carbonization tests were made on samples from two positions about six miles apart in the Kianga Coalfield, viz., at the Gibihi trial shaft No. S2 and at a box-cut near trial shaft No. 3. Both coals are high-volatile, weakly caking, low-sulphur coals, useful for the manufacture of town gas and coke.

(iv) *Effect of Storage.*—Changes in the coking and gas-making properties of coal during storage have been investigated over a period of 3½ years. Three coals from the Northern Coalfield of New South Wales were used, the Greta gas-making coal, the Borehole coal for coke manufacture, and the St. Heliers coal (Muswellbrook open-cut), for steam raising. Samples were analysed periodically and pilot-scale carbonization tests made. Heaps were freely ventilated, so that no heating of the coal occurred; in this respect conditions were better than those usually encountered in full-scale practice.

Exposure to weather causes a slow but progressive deterioration of most of the useful properties, though deterioration was not serious with large-size coals stored for only a few months. Quantitatively, the effect was less than is commonly supposed. The coking properties are not seriously impaired unless the coal becomes heated through being stored in large, poorly ventilated stockpiles.

(v) *Chemistry of Coke Formation.*—In the study of chemical reactions involved in the coking of coal, work continues on pyrolytic reactions and coking of model compounds—namely, a series of polynuclear quinones. This work has yielded information on the behaviour during heating of chemical groupings and structures considered present in coal. Electronic and vibrational spectroscopic techniques are used in elucidation of the structure of solid pyrolytic products. Concentrated sulphuric acid being the only solvent for many of the latter, the behaviour was studied of parent quinones in this solvent, to permit the interpretation of the spectra.

Background infra-red absorption was studied in pyrolysed brown and bituminous coals. All pyrolysed coals possess a long-wavelength absorption edge which progresses through the infra-red region towards longer wavelengths with increase in pyrolysis temperature. The behaviour of this background absorption of coals during pyrolysis is consistent with the formation and growth of condensed polynuclear aromatic structures.

(*b*) *Chemicals from Coal.* (i) *Chemistry of Coal.*—In view of the importance of coal as raw material for the manufacture of chemicals, research continues into its chemical nature. Coal is subjected to progressive chemical degradation and the resulting products studied. The nature, number, and position of functional groups and the arrangement of carbon atoms in the basic coal skeleton are determined.

Quantitative studies of the changes in the infra-red spectra of coals and chars that follow their acetylation indicated that the hydroxyl groups in many coals and chars are of the same chemical type. The oxygen which is not accounted for in the functional group analysis of Victorian brown coals is predominantly in the form of hydroxyl groups which resist acetylation and which appear stable on heating to about 450° C.

Measurement of absorption of sodium ions from ethanolic sodium hydroxide by Victorian brown coals and study of hydrolytic behaviour of their acetyl derivatives indicated the presence of alcoholic or very weakly acidic hydroxyl groups.

Previous work had indicated a simple relation between the ultimate composition and functional group analyses of Victorian brown coals and those of lignin, brown coals appearing to be essentially "demethylated-dehydrated lignin". To provide additional and independent data on the relation between lignin and brown coal, infra-red spectroscopic studies were made of brown coal, wood, cellulose, and lignin and some of its chemical derivatives. Comparison of the spectrum of a lignin with the spectra of its methoxyl and acetyl derivatives established the presence in the lignin of both alcoholic and phenolic hydroxyl groups. There appears to be a simple chemical relationship between the structure of brown coals and that of lignin.

(ii) *Properties of Light Oils, Tars, and Pitches.*—In relation to production of chemicals from coal, the Section is investigating the properties, composition, and structure of light oils, tars, and pitches produced by the carbonization of Australian coals. These studies are co-ordinated with parallel studies of the structure of coal itself.

Liquid by-products are being studied from low-temperature carbonization of New South Wales coals in fluidized beds. Low-temperature tars contain a higher proportion of polyhydric phenols than the high-temperature tars available commercially. The effect was studied of monohydric and polyhydric phenols, present in coal-tar and pitch fractions, in estimating the total phenolic hydroxyl content of these substances by non-aqueous titration. In admixture with 2,6-xylenol, the total acidic hydrogen of monohydric and polyhydric phenols was found to titrate with a single inflexion, even when the phenolic groups are hydrogen-bonded to adjacent carbonyl groups.

Investigation continues into the constitution and formation of pitch. Pitch formation during the distillation of tar results not from intercondensation of phenolic hydroxyl groups but from addition at unsaturated bonds and from substitution at positions activated by the phenolic hydroxyl group.

Functional group determinations have shown that at least two forms of phenolic hydroxyl groups occur in fractions of a pitch from a high-temperature tar, which are insoluble in light petroleum. Total hydroxyl contents higher than those obtained by direct titration were observed when a chemical method of estimation was used.

Vapour-phase chromatographic quantitative analysis has been extended to the estimation of naphthalene and its derivatives, and are being developed for the lower boiling tar acids and for high boiling neutral-oil fractions.

(*c*) *Combustion and Gasification.* (i) *Aerodynamic Factors in Coke Beds.*—Investigations have continued for improving the utilization of metallurgical coke in industrial appliances. The influence has been studied of macrophysical and other properties, such as the shape and size of coke, on the performance characteristics of industrial plant. A two-dimensional model was used to determine the distribution of air velocity in the coke bed, and the effect of coke size and cupola geometry on the penetration of the air blast from the tuyères into the bed. Penetration was increased by using larger coke and by downward inclination of the tuyères. The results were correlated with recent performance figures on full-scale cupolas. The ratio of coke size to model cupola diameter which gave maximum penetration corresponded to that giving maximum metal temperature in practice. A three-dimensional model is being used to study the air penetration in the plane of the tuyères.

To determine the best method of using coke fines, the pressure drop through beds of coke has been measured with a small-scale permeability apparatus. The effect has been investigated of coke size and of packing small particles of coke in the voids between large particles. These results are being applied to the design of a 2-ft. diameter voidometer for use with coke pieces up to 2 inches in size.

(ii) *Physical Structure of Cokes and Chars.*—When cokes and chars are gasified reaction rates depend on the physical structure of these materials—particularly on volume, shape, and internal surface area of the pores.

Changes in the pore structure of brown-coal chars during carbonization have been studied by density, surface-area, and mercury-penetration measurements. Brown-coal chars are similar to cokes prepared from bituminous coals, with two distinct pore systems—no pore entrances between 250 and 40Å, and the diameters of entrances in the micropore structure between 7 and 10Å. However, the decrease in accessibility of the micropore structure of brown-coal chars with increase in carbonization temperature is not nearly so marked as with cokes from bituminous coals.

The study of finely ground samples (minus 10μ) of cokes and chars has confirmed the existence of pores in the micropore structure with bottleneck entrances.

3. EXAMINATION OF COAL SEAMS.

(Coal Research Section.)

(*a*) *General.*—Detailed assessment of chemical, physical, and petrographic characteristics of selected coal seams and their sub-sections has been continued.

Profile samples were taken at six collieries in the Newcastle district of the northern coal-field of New South Wales representing the Great Northern, Borehole, Victoria Tunnel, and Wallarah seams. In the Maitland-Cessnock-Greta, East Maitland, and Muswellbrook-Singleton districts seven collieries were sampled representing the Greta, Rathluba, and Liddell seams.

In the Southern Coalfield of New South Wales a profile sample was taken of the Balgownie seam, and a bore core examined from the Wongawilli No. 11 bore, sunk in this area for Australian Iron and Steel Limited.

At the request of Australian Oil and Gas Corporation Limited, samples were investigated from the Mulgoa No. 2 bore in the Central Coalfield of New South Wales. In continuing the study of Queensland coals samples were examined from the upper and lower splits of the Fiery seam (presumed), North Ipswich district, and from a box-cut near trial shaft No. 3 on the Kianga Coalfield, Rockhampton district.

(*b*) *Mineral Matter in Coal.*—Mineral matter is present in all coal deposits. It may cause practical problems such as atmospheric pollution, troublesome deposits and slags in gas producers and steam-raising plant, corrosion of refractories, and undesirable contamination of metals during blast furnace or cupola operation.

Investigation continues on the direct determination of the total mineral-matter of Australian coals. Two direct methods—based respectively on low-temperature oxidation and on acid digestion—although reliable, both present some difficulties. A combined method has been developed overcoming these difficulties, and providing a direct means of estimating the water of hydration of the silicate minerals in coal.

The use of germanium in electronics has stimulated the search for indigenous sources of this rare element. Investigation of germanium, 24 other minor constituents, and trace elements in Australian coals is continuing. The ashes from the majority of the bituminous coals studied have a germanium content in the range 0.001-0.003 per cent. Highest values occurred in coals from the Burragorang Valley area of the Bulli seam, one subsection yielding ash containing 0.06 per cent. germanium. The Queensland coals examined are lower in germanium content than New South Wales coals, as also are the low-rank coals of Victoria, South Australia, and Western Australia.

Miscellaneous flue-dust and tar samples from Australian coals have been analysed for germanium. The only enrichment of importance was found in a sample of flue-dust from a waste-heat boiler at the Footscray gasworks, Victoria, where the plant had been carbonizing Greta seam coal. The sample examined contained over 1 per cent. of germanium.

Coal of low phosphorus content is essential for the manufacture of coke for the iron and steel industry and for steam raising. A new, rapid method has been developed for phosphorus determination in coal ash, using hydrochloric and sulphuric acids, giving results comparable with those obtained by the British Standard procedure using hydrofluoric and nitric acids, and avoiding the use of hydrofluoric acid.

(*c*) *Petrography.*—Petrographical studies of coal seams have continued and progress made in the application of petrology to the production of better metallurgical coke. In co-operation with the International Committee on Coal Petrology the methods are being studied for microlithotype and rank analyses.

Samples have been examined of coal collected by the trans-Antarctic expedition led by Sir Vivian Fuchs. They were of extremely high rank, some of their properties being close to those of graphite. They differed from other Antarctic coals from the Prince Charles Mountains, which resembled some New South Wales coals.

(*d*) *Washability Characteristics.*—Reduction of the mineral-matter content of coal by washing and cleaning can contribute to the more efficient utilization of coal.

The washability characteristics were determined of the Wongawilli seam (presumed) at the Mount Alexander Colliery in the South-western Coalfield of New South Wales. This seam consists of thermally metamorphosed coal with a very low volatile-matter content and a very high ash yield. It would be difficult to wash the coal satisfactorily, but selective mining of the bottom of the seam would give cleaner coal with better washability characteristics.

Washability tests made on samples from the Great Northern Seam at Normaine Colliery, Northern Coalfield, New South Wales, indicated that this coal could not be cleaned easily in a gravity separation plant, even if the coal were crushed to minus ½ in. prior to washing.

Coal from the Bulli seam at Nattai-Bulli Colliery, South-western Coalfield, New South Wales, has similar washability characteristics throughout the range of sizes which can be treated by gravity concentration, and separation at a specific gravity of 1.6 would present no practical difficulties.

4. MICROSTRUCTURE OF BROWN COAL.

(Pollen Research Unit.)

This Unit, at the Botany School, University of Melbourne, has dealt with the description and distribution of fossil microspores and megaspores of Upper Mesozoic and Lower Tertiary age. Several new genera and numerous new species have been described, and these and other new records have been used in correlating sedimentary deposits in most States of Australia and in New Guinea.

Microplankton studies continue, and new genera and species have been described from Australian Lower Cretaceous sediments. The distribution of these species was investigated, and new localities recorded for previously described species.

Studies continued of the pollen of Victorian brown coals, including collection of preparations of recent pollen for comparison with fossil ones.

5. UTILIZATION OF LOW-RANK COAL.

(Chemical Engineering Section.)

(*a*) *Gasification of Brown Coal with Hydrogen.*—Experiments continued on the hydrogenation of Yallourn brown coal in the continuously operated co-current fluidized bed reactor, to investigate the influence of hydrogen partial pressure (0-40 atm.) and temperature (750-950° C.) on the rate of gasification of the coal and the distribution of products.

Hydrogenation occurs in two fairly well-defined stages. The first stage, concerned with the removal of oxygen-containing functional groups and hydrocarbon side chains, is very rapid and occurs in competition with pyrolysis reactions. Under favorable conditions (i.e., high hydrogen partial pressure and high temperature) the products are predominantly methane and water. This stage appears complete when about 57 per cent. of the total coal substance is gasified. The maximum methane produced is about 6 cu. ft. and the hydrogen consumption about 8.5 cu. ft. per lb. of dry ash-free coal.

The second stage, in which the residual aromatic carbon structure is hydrogenated, involves a slower reaction. The rate of this reaction is directly proportional to the hydrogen partial pressure and is strongly dependent on temperature, the rate constant increasing by a factor of 15 between 750 and 950° C. Complete gasification of the brown coal would yield about 18.5 cu. ft. of methane and consume about 33.5 cu. ft. of hydrogen per lb. of dry ash-free coal.

The present co-current reactor with shallow (i.e., 38-inch deep) bed has now provided a good quantitative picture of the chemistry and kinetic features of the process. A practical reaction system is now being developed to enable gas of high methane content to be produced under thermally self-supporting conditions. Reconstruction of the plant is well advanced to incorporate the new counter-current reactor with a bed depth of 20 feet.

(*b*) *Carbon Gasification Reactions.*—With the completion of the study of the carbon-steam reaction at high pressures, work has been concentrated on the reactions of carbon with hydrogen and carbon dioxide. Study of the former system has shown that methane is formed by direct hydrogenation of the carbon, and a comparison of the methane formation rates for steam and hydrogen has shown that steam is equally as effective as hydrogen in producing methane from carbon.

The rate of methane formation for chars prepared in the temperature range 650-1,150° C. is related to the oxygen content of the char and at temperatures of the order 600-800° C., oxygen-free carbon cannot be hydrogenated. Certain oxygen groupings such as benzpyran structures are responsible for the reactivity of the carbon and the reactivity decreases as the number of these groups decreases.

For the carbon-carbon dioxide system the reactivity of the carbon is again a function of its oxygen content. The type of oxygen bonding is again specific and the evidence points to the group suggested above.

Behaviour of carbon towards atomic gases produced in a radio frequency field has been investigated jointly with the Division of Mineral Chemistry. In the reaction with atomic oxygen, which takes place at room temperatures, carbon monoxide is the only primary product of carbon and this, with other evidence, suggests that gasification processes proceed through the formation of atomic species.

(*c*) *Pore Structure of Coals and Chars.*—Study has been completed of the pore structure of brown coal briquettes using the high-pressure mercury porosimeter, and the influences of briquetting pressure and of moisture content on pore size distribution have been examined.

The application of briquetting pressure caused major reduction in the volume of interparticulate voids, and progressive crushing of macropores (125-40,000Å equivalent radius). Pores smaller than 125Å equivalent radius were unaffected. Most of the water was contained in the macropores where the addition or removal of water caused swelling or shrinkage of the briquette.

The influence of moisture content on briquette strength is probably related to its influence on the degree of crushing of macropores and thus the size of planes of contact developed between coal particles. This new evidence supports the so-called " capillary adhesion " theory of binding in brown coal briquettes.

In theoretical studies of porosimetry corrections to be applied to mercury porosimeter data, and the anomalous properties of irregular-shaped pores, have been reviewed.

XX. PHYSICAL METALLURGY.

1. GENERAL.

The Physical Metallurgy Section is a small research group at the Melbourne University Research School of Metallurgy, established by the Organization in co-operation with the university. The Section confines its research to specialized projects in the field of metallurgy, e.g. on titanium and its alloys and on metal deformation. The work of the Section is described in this Chapter. Work on metal physics is in progress within the Division of Tribophysics (*see* Chapter XXI.). Groups within the Chemical Research Laboratories are working in specialized fields of metallurgy, and these are reported in Chapter XVII.

Physical Metallurgy Section.—Research projects outlined previously have continued.

Mr. R. C. Gifkins, Principal Research Officer, attended an international conference on the fracture of metals, held at the Massachusetts Institute of Technology.

Members of the Section have assisted in supervision of University post-graduate students and organized further post-graduate discussion groups. The Section continues to receive and answer inquiries relating to metallurgical problems in industry.

2. TITANIUM AND ITS ALLOYS.

(Section of Physical Metallurgy.)

Work on the properties of titanium-niobium alloys at elevated temperatures has been extended to include the properties of titanium-niobium-aluminium alloys, and the effect of impurities and heat treatment on these alloys.

Study commenced of the embrittlement of certain types of titanium alloys, after heating into the beta phase field.

3. DEFORMATION.

(Section of Physical Metallurgy.)

(*a*) *Slow Deformation and Creep.*—Work described previously has continued and study of boundary migration has been reinterpreted quantitatively. Dislocation densities have been taken as the driving force, and oxygen segregated to the boundaries as the rate controlling factor.

To assess theoretical approaches it is desirable to know the stacking-fault energy of lead. Preliminary measurements have been made of twin-boundary grain-boundary energies.

A review of mechanisms of intergranular fracture, with some new quantitative treatments, has been made.

(*b*) *Boundary Sliding during Creep of Lead Bi-crystals.*—Bi-crystal specimens have been tested in creep at various stresses and temperatures. Measurements of creep within each crystal and across the boundary have been made and compared with sliding, measured parallel and perpendicular to the applied stress. Information on the zone associated with sliding and on activation energies has been obtained. Effect of temperature and orientation differences between the crystals is being studied.

(*c*) *Study of Creep of Lead Using an X-ray Microbeam Technique.*—The microbeam equipment has been calibrated and preliminary measurements made of depth of penetration of the beam and the "particle" size of cold-worked specimens. The effect of rate of strain on the particle size is being studied, and the local conditions near grain boundaries during creep are being investigated.

4. Analytical Methods.

(Section of Physical Metallurgy.)

Investigations were made to establish a standard colorimetric method for estimation of molybdenum in steels. This work was done in conjunction with the Committee for the Analysis of Ferrous Materials, Standards Association of Australia.

Spectographic analysis was used to determine the presence of oil additions in carbon deposits from tractor Diesel motors. This information is of interest to the Commonwealth Tractor Testing Station in connexion with efforts to reduce sparking from tractor exhausts.

XXI. TRIBOPHYSICS.

1. General.

Tribophysics is the physics of friction, and the Organization's Division of Tribophysics has developed from a war-time group of scientists studying problems of friction and lubrication. The original investigations of the Division have been continued and extended to include fundamental studies in metal physics and the physics and chemistry of surfaces of solids. The work of the Division of Tribophysics is described in this Chapter.

Division of Tribophysics.—The work of the Division has continued along the general lines described in the last Annual Report. There have been no changes in senior staff. Co-operation with several university departments has again proved to be of great mutual benefit. The colloquia held with other metallurgical groups continue to be an important medium for the exchange of specialized knowledge.

Advice and assistance have been given frequently to numerous industrial firms, government organizations, departments of various universities, and other Divisions of the Organization. The range of subjects—lubrication, bearings and bearing metals, wear, metals technology, electrolytic polishing, electronics, and surface chemistry—illustrates the way in which fundamental investigations of the Division are related to practical applications.

A grant has been given by H. C. Sleigh Ltd. to enable the Division to undertake a research programme on solid lubricants. Magnets of fine iron filaments have been the subject of co-operative research with Rola Co. (Aust.) Pty. Ltd. In addition, representatives of an oil company have been given lectures and demonstrations on lubrication and friction.

Members of the staff have taken an active interest in the formation of a new Division of the Institution of Automotive and Aeronautical Engineers concerned with problems of lubrication in industry and transport.

2. Properties of Surfaces.

(Division of Tribophysics.)

Statistical methods are being applied to industrial processes to reveal real differences between lubricants when used under practical conditions. Work on the physics and chemistry of solid surfaces is concerned mainly with the mechanisms of various processes for preparing a surface (ion bombardment, and thermal polishing and etching), the nature of the surface after preparation, and the effect of these treatments on adsorption, desorption, and catalytic activity. To learn as much as possible about one material, most experiments have been carried out on large crystals of silver.

(*a*) *Friction and Lubrication.* (i) *Lubrication of Bearings.*—Tests have been made on the performance of hardened steel journals running in nylon bearings. Nylon differs from conventional bearing materials in having low stiffness, low heat conductivity, and a tendency to change dimensionally due to absorption of oil, water, &c. A larger running clearance is required for this material and, in general, errors in the geometric form of the bearing are greater. Friction measurements have shown that, as the duty is increased, full fluid lubrication breaks down earlier with nylon than with rigid metal bearings. However, operation with thin oil films and partial hydrodynamic lubrication is extremely practical, since the transition to boundary lubrication is extremely smooth and is not accompanied by any signs of seizure or pick-up of material on the journal. Lubricated nylon and hardened steel therefore form a good bearing combination. In applications where the amount of heat to be dissipated is low; for example, heavy loads or low speeds, spasmodic operation, &c., nylon bearings show considerable promise.

(ii) *Lubrication by Solid Lubricants.*—Investigation has commenced on the possible use as lubricants of several new substances derived from Australian minerals. These lubricants have been prepared in the Chemical Research Laboratories for study of properties and uses, and typical examples are the sulphides of titanium and zirconium. The new materials show promise for applications similar to those of graphite and molybdenum disulphide and the investigation includes a general study of the mechanism of lubrication by these materials.

(iii) *Silicones.*—Some years ago, experiments were initiated to investigate the molecular structure of silicone oils (polydimethyl siloxanes) by determining the thermodynamic properties of their solutions. These measurements, primarily of the vapour pressures of mixtures with benzene of samples of the oils of three different molecular weights, over a wide range of concentrations, have now been completed and interpreted. The values of the free energies, when compared with those calculated from the statistical mechanical theory of polymer solutions, show that the silicone molecule behaves as an ideally flexible chain in these solutions. The simpler theories of the mixtures of polymers with solvents do not give satisfactory values for the change of entropy with progressive dilution, whereas the measurements can be completely interpreted by the more complex theories. This project is now concluded.

(*b*) *The Structure of Solid Surfaces.* (i) *Ion Bombardment.*—In earlier work the effects of sputtering, which is an efficient, frequently used method of cleaning metal surfaces of adsorbed layers, had been investigated on single crystals of silver. There are three main effects: (i) the rate of removal of silver depends on the orientation of the bombarded crystal, (ii) the surface after bombardment contains crystalline blocks (about 100Å wide and thick) rotated relative to the original crystal, and (iii) on the surface of an alloy, a thin layer of altered, but uniform, composition is formed.

Some atoms at the surface of a silver crystal are driven into the interior of the crystal by bombardment with positive ions. Disorientation produced by bombardment depends on the temperature of the target—the higher the temperature, the smaller the disorientation.

Small single crystals of silver have been bombarded with argon ions and the ejected silver atoms collected on glass plate to form "deposit spot patterns". Deposit patterns obtained from a silver surface showed no obvious variation with ion energy for energies in the range 20-4,000 eV. The patterns showed the same symmetry as the crystal face bombarded and the regions of heaviest deposition corresponded to the ejection of silver in close-packed directions.

(ii) *Thermal Etching.*—The production of fine ridges on the surface of silver when it is heated in air for several hours near its melting point has been studied by comparing the weight loss with changes in the geometry of the surface. In the early stages of etching the silver which evaporates is approximately equal to that which would have been contained in the valleys between the ridges. On further heating the evaporation continues but the surface contour does not change. The thermal etching may be produced initially by an evaporation process. The relation between this and earlier theories which explained the surface rearrangement in terms of minimum surface energy is being investigated.

(*c*) *Chemical Properties of Surfaces.* (i) *Adsorption of Oxygen on Silver.*—Thermal etching of silver only occurs when oxygen is present and at temperatures and pressures where silver oxide is unstable and oxygen dissolved in the silver. Adsorption is a prerequisite for solution and must occur, but no satisfactory quantitative data are available. Uniform silver powder has been prepared by filing and sieving. At 200° C. and 1 mm Hg pressure enough oxygen is taken up to form at least three monolayers. Although sorption is slow, it is at least partially reversible by pumping, indicating a low heat of sorption. In a parallel study of the adsorption of oxygen on silver crystals, the quantity adsorbed is being determined by cathodic reduction.

(ii) *Thermal Desorption from Silver.*—The rate of thermal desorption of stearic acid from a close-packed monolayer adsorbed on a plane surface of a silver crystal depends on the crystallographic orientation of the plane, being lowest for (110) and highest for (100) and (111). The extent of the anisotrophy of desorption rate varies with the method of preparation of the silver surface. If the surface is bombarded with argon ions, the anisotropy is smaller the lower the bombarding voltage and at 22½ V can no longer be detected.

(iii) *Catalysis on Single Crystals of Silver.*—Crystal surfaces which had been bombarded with argon ions were thermally etched and used as catalysts in the decomposition of formic acid. As facets of low index planes appear depending on the original orientation, a lowering of the experimental activation energy of the reaction is observed. The investigation has been extended to the decomposition of hydrogen peroxide in aqueous solution.

3. METAL PHYSICS.

(Division of Tribophysics.)

The aim of this work is the design of materials of specified properties, thereby widening the range of materials available to industry. This necessitates a better understanding of the nature of strength and the mechanism of plastic deformation. The forces holding the atoms together in a metal crystal indicate a strength about a thousand times larger than that usually observed. The reason for the low strength is that most crystals contain various types of defects, particularly dislocations (displacements of atomic planes in a vernier-like fashion), stacking faults (extended dislocations), and point defects (vacant lattice sites, impurity atoms, and atoms in interstitial positions). To understand the origin of hardening occurring during plastic deformation, the type, the number, and the arrangement of defects in plastically deformed crystals must be known. To determine these it is necessary to correlate measurements of as many properties as possible made on the same material. Investigations described earlier on pure metals have been continued, but emphasis has been placed on investigations of lattice defects in alpha brass (70 per cent. copper, 30 per cent. zinc).

(*a*) *Arrays of Dislocations.*—The equations describing the mutual interaction of a group of dislocations are of a complicated type and cannot be solved mathematically except in special cases. A general method for solving such problems numerically using an electronic computer has been developed. This has been used to obtain detailed information about some dislocation arrays of physical interest for which there was previously only qualitative information.

(*b*) *Lattice Defects and the Order-Disorder Transformation in Alpha Brass.*—When point defects have been generated in pure metals by neutron irradiation or by quenching, these metals show "overshoot" and develop coarse slip bands during plastic deformation. In addition, after such treatments pure metals harden on annealing. Alpha brass in its normal annealed state shows overshoot and develops coarse slip bands during plastic deformation and hardens on annealing after deformation. Thus, an investigation of the role of defects in plastically deformed alpha brass is one way of studying the general problems of the role of defects in deformed, irradiated, or quenched metals.

In the past, the role of defects (both point defects and dislocations) in the deformation and annealing behaviour of alpha brass has been masked by the unknown role of order in this material. The existence of a super-lattice in alpha brass has now been demonstrated by measurements of energy, resistivity, and density. However, this super-lattice does not make any net contribution to the changes in properties which occur on annealing deformed or quenched alpha brass. The measurements also show that very high concentrations of point defects may be obtained by deformation or quenching and that such concentrations may be made possible by a strong interaction between the point defects and solute atoms. Large anomalies are observed on comparing the magnitudes of the energy, density, and resistivity changes in both deformed and quenched specimens and these anomalies may be explained by clustering of vacancies. In addition, unusual decreases in resistivity and density suggest that such clustering is associated with segregation of zinc.

The hardening which occurs on annealing deformed alpha brass is associated with the vacancy energy released below the recrystallization temperature. However, the hardening is not due to vacancies alone, since such hardening does not occur in quenched specimens. The measurements indicate clearly that hardening is not caused by the return of order destroyed by cold work. To elucidate the mechanism of hardening, the tensile behaviour of single crystals is being investigated in addition to the usual measurements of energy, density, and resistivity.

(*c*) *Point Defects.*—Investigation has continued on point defects in deformed and quenched pure metals.

(i) *Nickel.*—Energy measurements on deformed nickel of the highest purity used have shown the existence of an annealing stage at a lower temperature than that associated with the annealing of vacancies. Interstitials as well as vacancies may be generated during plastic strain. In co-operation with the Watertown Arsenal, U.S.A., the annealing behaviour of deformed nickel powder of extreme purity is being studied and it is hoped that energy measurements will assist in the elucidation of neutron diffraction studies at that laboratory.

(ii) *Deformation at Low Temperatures.*—In all previous work on the generation of point defects by plastic deformation the plastic straining has been done at room temperature. By reducing the temperature of deformation to that of liquid air much higher point defect concentrations can be obtained in alpha brass, even after allowing the specimen to warm up to room temperature prior to measurement. These measurements will be complemented by those with the low temperature calorimeter.

(iii) *Low Temperature Calorimetry.*—In pure metals of low melting point the study of point defects is restricted because of their high mobility. To avoid this restriction, a calorimeter has been constructed to study the release of energy, from specimens deformed in liquid air, between the temperature of deformation and 100° C. One of the major difficulties associated with low temperature calorimetry on deformed metals is the machining of specimens at low temperature. This difficulty has been overcome by using specimens in the form of spools of wire which is drawn and rolled on formers under liquid air. Tests of these specimens in the standard differential calorimeter show that they are satisfactory.

(*d*) *Grain Size.*—The influence of grain size on the energy stored and on the mechanical properties of copper has been investigated. Results elucidate the work hardening behaviour of polycrystalline aggregates. However, the persistently low recrystallization temperature of fine-grained specimens, and an unexpected energy release prior to recrystallization observed only in these specimens, are being investigated further. Experiments are in hand which have been designed to isolate the role of segregated impurities and thus aid in the interpretation of the above observations.

(*e*) *Structure of Deformed Metals.*—It has been reported previously that X-ray diffraction lines of plastically deformed metals are broader than those of undeformed metals and that Fourier analysis of the line shape allows separation ofthe two effects causing this broadening, i.e. lattice distortion and fragmentation. A new technique had been developed to determine the line shape obtained from bulk specimens (as distinct from powders) even in the presence of preferred orientation. Nickel specimens have been deformed by compression and subsequently annealed at various temperatures, and the results of the analysis of the line shapes are being correlated with measurements of other properties such as stored energy and electrical resistivity.

(*f*) *Nuclear Magnetic Resonance.*—Last year the large "Varian" electromagnet was installed and a programme has now been undertaken to explore the application of nuclear magnetic resonance techniques to problems of metallurgy and solid state physics.

The first experiments were made to check a statement in the literature that the resonance line of copper is absent in the ordered structure of beta brass containing 50 atomic per cent. zinc. Current experiments have shown the presence of this line with a strong intensity. The failure of the previous workers to detect the line is probably due to the use of an alloy of slightly different composition. It was also found that the line can be eliminated almost completely by plastic deformation.

In pure copper, plastic deformation by rolling produces no change in shape of the resonance line nor of its width, unless the deformation gives rise to preferred orientation. On the other hand, the intensity of the line is decreased by deformation. Correspondingly, on annealing of the rolled sheet in the temperature range of recrystallization, the line intensity increases without apparent change in line shape.

XXII. NATIONAL STANDARDS LABORATORY.

The National Standards Laboratory, consisting of the Divisions of Metrology, Physics, and Electrotechnology, maintains the Commonwealth standards of measurement and calibrates precision measuring equipment in terms of those standards (see Chapters XXIII., XXIV., and XXV. respectively).

The Commonwealth *Weights and Measures (National Standards) Act* 1948, provides for the States of the Commonwealth to continue to administer under State acts matters relating to weights and measures in trade and commerce. The Organization under this act is responsible for the Commonwealth standards of measurement.

Close liaison has been maintained with the Bureau International des Poids et Mesures whose Director conducted the negotiations enabling the Laboratory to acquire a platinum-iridium prototype metre. A meeting of the Committee of the Bureau was attended.

The Director took part in discussions with the Directors of the National Institutions in Canada, New Zealand, United States, United Kingdom, and South Africa. It was agreed to adopt an international yard and international pound and that all non-metric measurements for science and technology made on and after 1st July, 1960, will be in these international units.

Members of the staff have taken part in Committees of national organizations and have given technical assistance to other Government Departments and to bodies such as the National Association of Testing Authorities.

The work of the Laboratory was displayed to the scientific and technical community on two Open Days. The large number of visitors and subsequent inquiries are a measure of the success of this event.

XXIII. METROLOGY.

1. GENERAL.

Accurate measurement is essential to the manufacturing and engineering industries in Australia. Measuring equipment must be regularly calibrated against appropriate working standards. These in turn require periodical calibration in terms of national and international standards.

The work of the Division of Metrology which maintains some of the national standards of measurement is described in this Chapter.

Division of Metrology.—The work of the Division has followed the lines described in previous reports. Pressure is increasing on the calibration and consultative services offered by the Division. Two summer schools on geometric analysis of engineering designs were required this year to accommodate the number of applicants.

Officers of the Division gave a series of lectures on engineering design techniques to fourth year engineering students at the University of Sydney.

2. LENGTH AND ASSOCIATED QUANTITIES.

(Division of Metrology.)

(*a*) *Standards.* (i) *Line Standards.*—The Division has purchased one of the original platinum-iridium Prototype Metres, No. 20, to be used as the reference line standard for the Commonwealth of Australia. This Metre, which will meet the need for a stable reference standard, is to be repolished and regraduated by latest techniques by the Société Génevoise in Geneva. Subsequently, it will be calibrated in terms of the International Prototype Metre by the Bureau International des Poids et Mesures and should arrive at the National Standards Laboratory early in 1960. This standard will carry the appropriate graduations for the yard as well as the metre.

Temperature control has been further improved within the tanks of the Line Standard Comparator. An experimental tank and control system has given a stability of 0.01° C. over periods of 6 hr. with a uniform gradient of the same order from end to end of the tank.

(ii) *End Standards.*—Improvements have been made to the various interferometers used for the calibration of slip gauges, particularly a device for the direct measurement of the fringe fractions.

(iii) *Angle Standards.*—The Division's sets of angle gauges have been recalibrated by a systematic series of intercomparisons of single gauges and of gauges in combination. The " least squares " adjustment of the results was carried out on an automatic computer. Agreement within 1 sec. of arc with previously accepted values for the gauges was obtained. This was considered satisfactory in view of the period between the calibrations (average seven to eight years).

(iv) *Surveying Tapes.*—The long-term reliability is being investigated of the sag wires on the geodetic base as a means of determining the length of specific intervals of the base with sufficient accuracy for calibration of tapes to 1 part in 10^5. Results to date indicate that these specific intervals may be determined from sag measuremeans to an accuracy of $\pm$ 3 parts in 10^6.

Further progress has been made with the construction and installation of the 4 m. line standard comparator, which should be in operation early in 1960.

A number of tapes have been calibrated on behalf of other authorities. One of these, a 50 m. invar tape, exhibited a sudden change in length of ± 3 parts in 10^6 between the first and second sets of measurements during calibration.

(*b*) *Interferometry.*—(i) *Length Interferometry.*—The production is well advanced of an interferometer for measuring a 1 m. line standard in terms of light waves. The instrument provides means for both static and dynamic measurement, and electronic fringe counting equipment is being constructed for this work.

A 1 m. end standard interferometer is also nearing completion.

The determination of distances greater than 1 m. is being investigated for the purpose of establishing geodetic base lines by interferometry. Problems of vibration within the building still have to be solved, but compact optical equipment is being designed for this work.

Further studies have been done on the relation between the reflection characteristics of steel surfaces and the optical phase change at reflection. The evaluation of this latter effect is a significant source of error in high precision measurement.

(ii) *Wavelength Measurement.*—Progress has been made with the measurement of vacuum wavelengths using an oscillating-plate variable-gap Fabry-Pérot interferometer. Photoelectric detection methods are used and the sensitivity of setting is of the order of 0.001 fringe. The electromagnetic plate holders were designed and made by the Division of Electrotechnology. A model of the electrical control unit is now under construction and should enable two spectral lines to be measured almost simultaneously. Provided care is taken to avoid temperature effects, and a photocell of adequate response is used, wavelengths can be compared with an accuracy of 1 in 10^8. This equipment will be used in detailed studies on various spectral lines.

(iii) *Light Sources.*—Equipment has been set up for the making and filling of lamps that will be used as sources of standard wavelengths. Several mercury-198 isotope lamps have been made, and work on other lamps including those containing krypton-86 and cadmium-114 isotopes is in progress.

(iv) *Photoelectric Microscope.* — An experimental model has been constructed for the line standard interferometer, and a more universal model is under development.

(v) *Thin Films.*—The adhesive properties have been investigated of evaporated metal coatings on glass, and the results are being applied to the production of optical graticules.

Various coatings of thin films including metals and dielectrics were supplied to other Sections, Divisions, and outside bodies.

(*c*) *Engineering Metrology.* (i) *General Measurement and Consultative Service.*—The examination and calibration has continued of all types of measuring tools, equipment, and gauges. The examination of machine tools and components has also continued.

Work related to production and inspection gauging undertaken on behalf of the Department of Supply has continued throughout the year. A considerable amount of measuring equipment was examined on behalf of the National Association of Testing Authorities.

As in previous years assistance has been given on a wide variety of measurement problems referred to the Division by industrial organizations and other departments.

The facilities have been extended by the gift, from the manufacturer, of a portable surface-finish measuring instrument. The probe of this instrument is motor operated and the C.L.A. meter readings are thus not dependent on the skill of the operator.

(ii) *Gears.*—A large double-helical marine gear wheel was examined for errors in transverse pitch on behalf of the Department of Supply. A similar gear wheel was also examined for transverse pitch errors on behalf of the Department of the Navy; this gear wheel was actually measured mounted in the gear box of a ship.

A set of flexible gear couplings was inspected on behalf of the Department of the Navy and a technique was devised whereby metallic replicas of specific gear teeth were obtained in " Cerrobend ". These replicas will provide a permanent record for the assessment of progressive wear and damage to the teeth.

A number of other types of gears, including spiral bevel and zerol bevel gears, were examined on behalf of industrial organizations. A fixture for the routine testing of zerol gears was also examined.

(iii) *Air Gauging.*—The experimental unit for the continuous gauging of linoleum during production has proved successful in operation.

A pneumatic fiducial indicator was developed for use with an internal screw thread diameter measuring machine. An experimental set-up showed that repetition, from either direction of approach, was of the order of 0.00001 inch. The final design is now complete and manufacture is proceeding.

A series of special twin jet measuring heads have been designed and manufactured to enable the reflecting surfaces of the two optical flats in a Fabry-Pérot interferometer to be set a specified distance apart with an accuracy of 1 μ. This greatly reduces the subsequent computations required in the normal use of the interferometer.

Measurements of two more coils, to be used in a research project of the Division of Physics, has been completed on the special apparatus developed for the purpose. Measurements " over the wires " were made at 530 positions on each coil; the accuracy, with only a very few positions excepted, being $\pm$ 1 μ. The use of gauging has continued in the routine measurement of slip gauges, reference ring gauges, and the cylinders of dead-weight pressure gauge testers.

(iv) *Hardness Indenters.*—The measurement of the flank angles of the diamond cones of Rockwell hardness indenters to an accuracy of the order of 1 min of arc can now be undertaken using an interference microscope for the alignment of the cone flank with a datum plane. The angles of Vickers diamond pyramid and Knoop indenters may also be measured using appropriate standards.

(v) *Screw Threads.*—Following the recognition of the Laboratory by the American Petroleum Institute as an authorized testing agency for A.P.I. taper screw gauges (including the fast taper gauges), a number of sets of regional master gauges are now held in the Division for both cable and rotary drilling tool joints suitable for the standardization of reference master gauges.

(vi) *Dividing Engines.*—The main bearings of the circular dividing engine were overhauled and a check calibration of the engine was carried out using precision polygons as the reference standards. The results agreed with the previous calibration within 1 sec of arc.

A number of scales, including that for the Division's primary standard barometer, have been ruled on the engines. An investigation is in progress to determine the best primary metal in the double evaporation process for the production of scales on glass.

(vii) *Lapping Investigations.*—The apparatus for sharpening needles has been further developed into a satisfactory and compact unit. The machine gives excellent results on all sizes of needle, from the blood-taking needle of 14 S.W.G. to the fine hypodermic needle, 26 S.W.G. Arrangements have been made for its commercial production.

An increasing number of inquiries are being received on various applications of precision lapping.

3. MASS AND ASSOCIATED QUANTITIES.

(Division of Metrology.)

(*a*) *Standards of Mass.* (i) *Mass Standards.*—The computations of values of the metric standards included in the comparisons mentioned in a previous report have been completed. The overall position in regard to the stability of the reference standards of stainless steel appears to be satisfactory. The standards of nickel-chromium continue to exhibit a decrease in mass, relative to the stainless steel standards.

The high-precision 1-kilogram balance acquired for the comparison of the primary standard kilogram with the references has been installed. This balance, which permits of the comparison of standards without the necessity of opening the balance case once the loads have been poised, will enable the comparisons of the primary and the reference standards to be made to a higher order of accuracy than has hitherto been possible.

(ii) *Barometric Standard.*—The construction of the primary standard barometer mentioned in the previous report is now approaching completion. The main mechanical construction, glassware, and scale are complete and the setting technique has been thoroughly tested.

The pressure controller developed and made in the Division has been in regular use in the testing of barometers.

(iii) *Density Measurement.*—Two independent determinations have been made of the density of the petroleum fractions used for the hydrometer calibrations and at the same time a calibration was made of two very sensitive hydrometers used for regular checks on the density of this liquid. As a result of this work, it is considered that the basis of calibration of hydrometers is established to within 0.00002 g per ml in the temperature range 15-21° C.

(iv) *Photogrammetry.*—The calibration of aerial cameras and research and development work associated with it has been continued.

An investigation has been made into the change in distortion pattern produced by a general shift of principal point and a satisfactory solution obtained.

The effect is being studied of the use of glass camera ports in aircraft on the metrical properties of the image.

Proposed definitions of terms used in photogrammetry were further revised and amended.

(v) *Consultative and Calibration Service.*—The quantity of test work received continues at a steady level and includes sets of analytical weights, volumetric glassware of various types, hydrometers, pycnometers, balances, barometers, stop-watches, interval-timers, and photogrammetric cameras.

4. APPLIED MECHANICS.

(Division of Metrology.)

(*a*) *Measurements of Physical Quantities.* (i) *Force.*—Steps have been taken to increase facilities available for calibration of testing machines. The provision of equipment for calibrating proving devices is still under consideration.

(ii) *Hardness.*—Additional equipment has been obtained. Work is proceeding on some sources of error in hardness testing machines.

(iii) *Impact.*—Improved techniques for calibrating impact machines are now on trial.

(*b*) *Vibration.* (i) *Vibration Isolation.*—Theoretical and experimental studies have continued of mountings of large machine tools. Aspects under study include properties of mountings, critical parts of machine tools' response to steady-state and transient vibration from external sources, self-induced vibrations, and relative motion between the cutting element and machine frame. Performance tests on large machine tools have been analysed.

The principles of seismic mounting were applied to a large photolitho copying camera of 7½ tons, installed on a site subject to severe vibration. A 1-ton experimental seismic block is about to be installed for the study of vibration isolating properties of materials and isolators.

The survey of literature on vibration and shock isolation in 1954 has been completely revised and issued as N.S.L. Technical Paper No. 10.

(ii) *Vibration Measurement.*—Additional equipment has been developed and a prototype acceleration transducer is on trial in service.

(iii) *Dynamic Balancing.*—Assistance was given to the Engineering Group Committee of C.S.I.R.O. and the Department of Supply in the revision of an Australia-wide survey of facilities for dynamic balancing.

(iv) *Vibration Services.* — These include vibration measurement on a gear box for a warship, location of the best site at a factory for an examination by sensitive instruments of a structure where it was suspected that cracking was caused by vibration, and testing rubber isolators.

(*c*) *Engineering Design Analysis.* (i) *Design Techniques.*—Following the pattern of previous years, much attention was given to the teaching of the subject. Two summer schools were held this year in the Division.

The previous summer school held in February, 1958, was designed specifically for University and Technical College lectures. This year's school, however, was offered not only to lecturers, but also to design departments of the Department of Supply. The response was so great that it was decided to run two schools. Total attendance was 30, fifteen at each school. The principles of geometric analysis were outlined in thirteen lectures, and 50 problems were given to the participants to solve. At the conclusion of each school, sets of model answers to the problems were distributed.

Techniques developed in the Division were used in analysing a functioning requirement for a time switch. The company concerned supplied data on all the dimensions involved from samples selected from production. The data were used to estimate the expected variation in the functioning dimension, and this result was compared with that obtained using the technique developed in the Division. The agreement obtained was satisfactory.

To study the effect of the shape of contributing frequency distributions in the general problem of an assembly involving a number of dimensions, an experiment was conducted to determine the final distributions obtained with samples of three and four taken at random from distributions of known shape. Three different shapes were chosen for the frequency distributions, viz., rectangular, triangular, and trapezoidal. First results show that the distributions for the dependent assembly dimensions are closely normal. The results of such investigations will be used to demonstrate the safety of the Division's recommendations to engineers.

(ii) *Process Variability.*—The study has continued ot typical machining operations using the techniques of dimensional analysis, including drilling and tapping of various copper and aluminium alloys and the turning of steel. The latter investigation was carried out for certain operations on an automatic lathe producing small steel screws. The results from the experiment are being programmed for analysis by automatic computer.

(*d*) *Machining Research.* (i) *Machinability of Australian Materials.*—Collaborative work has continued with the Broken Hill Proprietary Company Limited, and the machining characteristics have been investigated of two types of their free-machining steel. Long-life tests were correlated with a quick facing test used in the Division for assessing machinability. Satisfactory results have been achieved, and the method is now being introduced at the Australian Iron and Steel Company's works at Port Kembla to check the machinability of each individual heat. It is considered that similar techniques could be used by individual factories in assessing the machinability of batches of steel.

The facing test is not suitable for testing the machinability of small-diameter bar stock, and a parting-off test, carried out on automatic machines, is being investigated. First tests were made on an aluminium alloy and proved successful; they will now be extended to the free-machining steels.

Work has proceeded on the relation between microstructure and machinability of steel. Several bars of medium carbon steel were heat treated to give different grain sizes, and then machined under standardized conditions with high speed steel and tungsten carbide cutting tools. Results are being assessed to ascertain whether there is any relation between grain size and tool life, surface finish, and power consumption.

(ii) *Cutting Tools.*—Tests have proceeded on the performance of ceramic cutting tools under varying conditions of feed, speed, and depth of cut. The number of different types of ceramic tools has been increased to nine, and these represent widely varying sources of supply throughout the world. The tests have been retarded by lack of suitable equipment, and await the completion of modifications to an existing lathe. Smeared layers of work material were discovered on the wear land of the cutting tool, giving a much larger value for the tool wear than had actually taken place. This hitherto unsuspected smeared layer may explain some overseas reports of satisfactory cutting action of the tool even although abnormally large wear scars had formed.

A new type of boring bar was developed in connexion with the deep-hole drilling investigation and a few preliminary tests have been made with the tool in boring SAE 1016 steel. No further work was possible on the Kolesov type of tool because of lack of a suitable machine tool.

(iii) *Basic Research in Machining.*—Work has begun on the study of the metal cutting process which is a very complex physical and mechanical phenomenon. Experiments and techniques are being developed to measure cutting forces, cutting temperatures, and the like. The geometry of chip flow has been analysed, a study of tool wear has been made, and the geometry of chip curl has been examined in relation to the mechanism of cutting. A quick-stop tool dynamometer has been designed to enable the cutting process to be "frozen" and a device designed for measuring the stress distribution at the chip-tool interface.

(iv) *General.*—The special multi-channel recording instrument is now complete for use with a strain gauge dynamometer for measuring tool forces. The instrument is functioning satisfactorily.

XXIV. PHYSICS.

1. GENERAL.

The techniques of physics are basic to other sciences, and are used in varying degrees in all scientific work. To be effective instruments for physical measurement must be standardized and calibrated against approved standards.

The Division of Physics as part of the National Standards Laboratory is responsible for the maintenance of standards of measurement in heat, light, hygrometry, and viscometry, and for the calibration of instruments and equipment for science and industry in terms of these standards. It undertakes the development of new measuring techniques, *ad hoc* researches, and consultative work for industry, and is also engaged in fundamental research in solid state physics and solar physics.

This chapter describes the work of the Division of Physics. The Division's work on solar physics is described in Chapter XXVIII., Section 2.

Division of Physics.—Dr. G. H. Briggs retired during the year as Chief of the Division. His successor is Dr. R. G. Giovanelli, formerly head of the Light Section. During the year Dr. Giovanelli visited a number of overseas solar observatories.

As part of the Division's programme of assistance to industry two courses have been given in industrial pyrometry, with some 28 trainees from the various States. Assistance was rendered to the Commonwealth Department of Supply on problems associated with the storage of large quantities of liquid gases. Other co-operative work includes the development of a 21 cm. maser conjointly with the Division of Radiophysics, leading incidentally to the discovery of anti-maser effects in ruby at low temperatures.

Advances have been recorded in several instrumentation fields, particularly those of hygrometry, viscometry, and current stabilization; while observations of granulation in the photosphere and in sunspots have shown the need for considerable reorientation of ideas regarding these phenomena.

Researches into the photometric and colorimetric properties of diffusing media have been supported in part with funds contributed by C.S.R. Chemicals Pty. Ltd.

2. MEASUREMENT AND CONTROL OF TEMPERATURE.

(Division of Physics.)

(*a*) *International Temperature Scale.*—The ever pressing demands of science and industry necessitate continuous research on the realization, improvement, and extension of the International Temperature Scale. Plans are well advanced for realizing to high accuracy the freezing point of zinc, recognized by the International Committee of Weights and Measures as a more reproducible fixed point than the boiling point of sulphur. A high-accuracy manometer is being set up for the improved realization of the steam point, the mercury surfaces being located relative to standard end bars by capacitance measurements. With an experimental photo-electric disappearing-filament pyrometer a reproducibility of better than ± 0.1° C. has been attained at 1,100° C. Other work has been undertaken with a view to the extension of the International Temperature Scale below its present limit at about — 183° C.

(*b*) *Temperature Measurement.*—Calibrations of temperature measuring equipment during the year have included tests on over 50 industrial furnace installations, 40 secondary standard thermocouples, and 300 thermometers. Improvements in testing facilities have included the design of a special salt bath for precision calibrations of resistance thermometers and thermocouples up to 750° C., while a programme-controlled tube furnace with a two-coordinate recorder system is being set up for calibration of secondary standard thermocouples to 1,100° C.

Problems on which the Division has been consulted have included measurements of stored energy in irradiated material, the design of a low temperature chamber for testing aeronautical instruments, the measurement of temperature at the surface of foundry sand moulds, and the formulation of specifications for the thermal performance of special heat-treatment furnaces.

(*c*) *Cryogenics.*—The cryogenics laboratory is in a position to supply adequate quantities of liquid air and liquid helium to meet present requirements for refrigerants in low temperature and solid state research, but, with additional experimental equipment coming into use and proposals for co-operative research with the Atomic Energy Commission and the University of New South Wales, these facilities are becoming strained.

A second large vessel is therefore being acquired for the storage of liquid air, and a duplicate of the main body of the helium liquefier is under construction.

3. SOLID STATE PHYSICS.

(Division of Physics.)

(*a*) *Transport Phenomena and Thermal Expansion.*—Low temperature studies of electrical and thermal conductivities of solids have been continued, and are proving a powerful method of investigating the basic structure of metals, alloys, glasses, and dielectrics. This work is being extended to include measurements of thermoelectric forces and of the co-efficients of thermal expansion. Equipment is also under construction for measuring the thermal conductivity of solidified rare gases, which it is hoped will yield information on thermal conduction by crystalline lattices.

Measurements of the thermal conductivities of a number of copper and gold alloys have enabled the interaction between electrons and lattice waves to be studied and densities of dislocations, point defects, and other lattice imperfections to be deduced. It has been found that a large number of dislocations are retained during annealing of alloys, and these depend on the concentration of solute atoms. As a function of annealing temperature the variation of lattice thermal conductivity of a copper-zinc alloy has been studied and correlated with changes in other physical properties.

An exhaustive review has been completed of thermal conduction in solids by lattice vibrations, and the theory of thermal conductivity of non-crystalline or highly disordered solids has been extended, enabling the nature of structural correlations to be deduced from the temperature dependence of the thermal conductivity.

Experimental techniques have been modified for measuring thermal conductivity to permit more rapid measurement by replacing the gas thermometers, previously used for measurements of temperature differences with thermocouples.

(*b*) *Paramagnetic Resonance: The Maser.*—The paramagnetic resonance spectrum of sapphire (aluminium oxide containing ferric ions) has been measured with good accuracy at several temperatures. Because the crystal lattice, unlike that of most substances hitherto studied, is relatively simple and well known, these results provide an unusually precise test of the theory of paramagnetism. The work has been facilitated by the construction of a paramagnetic resonance spectrometer in which the specimen may be rotated to any orientation in a magnetic field without being remounted.

In collaboration with the Division of Radiophysics a ruby maser is being developed as a highly sensitive amplifier for radio astronomy. The frequency, 1,400 megacycles per second, corresponds to the well-known emission line of hydrogen. Good progress has been made, maser effects having been obtained first in October, 1958. A low-field (300 gauss) mode of operation obtained at liquid air temperatures failed to persist to liquid helium temperatures, although a 2,000 gauss mode was satisfactory; this unexpected behaviour is still unexplained. The maser apparatus has been used to measure paramagnetic spin-lattice relaxation times between 90 and 55° K. Temperature variation is more gradual than expected.

A survey has been made of substances suitable for use in a maser which would operate (at fixed frequency) without a magnetic field. Measurements on aluminium acetyl-acetonate containing a small proportion of iron have shown that it would be suitable for a zero-field maser and the frequency of amplification would be 9,350 Mc/s —practically at the centre of the familiar 3 cm. radar band.

4. HYGROMETRY.

(Division of Physics.)

Apart from the calibration of hygrometers and provision of assistance in the solution of a wide range of problems of humidity measurement and control, effort has been concentrated for some years on the development of new methods of hygrometry. These have resulted in instruments of high precision, and instruments for use at low humidities, or for making "spot" measurements without significantly affecting the environment.

(*a*) *Electrolytic Condensation Hygrometer.*—In this instrument, which is of high precision and rapid response, the gas to be examined is brought into controlled thermal equilibrium with a water-soluble crystal at such a temperature that the vapour is in equilibrium with a layer of saturated solution formed on the crystal. Patents have been granted in the United Kingdom, the United States of America, and Australia, and a commercially made hygrometer should soon be available. The basic physics of the technique is now well understood, and extensive measurements of eutectic temperatures and of hydrate transformation temperatures have been made on substances which could be of value for hygrometer crystal elements.

(*b*) *Hygrometric Probe Technique.*—The probe hygrometer has been developed for field work in biology and agriculture where rapid measurements of microenvironment are required at an accuracy of about ± 1 per cent. relative humidity.

The probes, which comprise small humidity-sensitive disks of anodized aluminium on a supporting stem, can now be produced simply and cheaply. They are used with a simple electronic indicator and can be calibrated *in situ* over the whole range from 10 to 90 per cent. relative humidity in about 15 min. The hygrometer and calibrator units are both portable and require only infrequent attention.

5. VISCOMETRY.

(Division of Physics.)

(*a*) *Capillary Viscometers.*—A troublesome source of uncertainty in capillary viscometers is the kinetic energy correction which arises from the non-linearity of the equations of fluid motion. The effect is found to be negligible with capillaries whose ends are long smooth flares, in contrast with the present uniform capillaries. The flares can be produced quite simply by applying gas pressure to a uniform capillary heated in a suitable temperature gradient.

This feature has been incorporated in completely sealed glass viscometers to study the relative viscosity of water as a function of temperature. Fine platinum wires serve to establish the water levels for timing purposes; with flow times recorded directly on an electronic counter and temperature controlled to ± 0.001° C., reproducibilities of 1 part in 50,000 are obtained.

(*b*) *Viscosity Ratiometer.*—This new instrument reads the ratio of the viscosities of two liquids directly. It consists of a balance supporting two vertical plates. These are immersed in the two liquids, and are then allowed to drain freely. The balance soon assumes a steady deflection which depends solely on the ratio of the two viscosities. The ratiometer has numerous industrial applications, wherever a rapid result is required to an accuracy of a few per cent., and where ease of cleaning is an advantage.

6. PHYSICAL AIDS TO SURGERY (HEART-LUNG MACHINES)

(Division of Physics.)

Instrumentation for use in hypothermia, the lowering of the body temperature, has been brought to an advanced stage over the last few years. While this has provided a valuable aid to cerebral and heart surgery, there are many cases where surgery can be attempted only if the heart can be stopped for longer than is allowable under hypothermia. With this in view, exploratory work has been begun on a "heart-lung" machine for the extracorporeal oxygenation and circulation of the blood. It is non-foaming, simple in operation, and requires a relatively small quantity of blood for priming. Preliminary measurements indicate that the method used, in which the blood flows down a suitable helix in an oxygen atmosphere, is remarkably efficient.

7. ATOMIC CONSTANTS.

(Division of Physics.)

Proton Gyromagnetic Ratio.—Experiments are in progress to determine the gyromagnetic ratio of the proton by a method involving a current balance for measuring the strength of the magnetic field. Errors due to the effect of the current-carrying coil on the field are being examined, and it is hoped to be able to reduce them considerably.

8. PHOTOMETRY AND COLORIMETRY.

(Division of Physics.)

(*a*) *General Photometry.*—A heavy demand has continued for calibrations of lamps, photometers, haemoglobinometers, photocells, and thermopiles, measurements of the colour and other optical properties of various materials, and of the spectral energy distributions of light sources. Facilities for calibrations and research have been improved by the installation of a second photometric bench.

A long-standing problem in photometry, radiometry, and optical pyrometry, and in many cases the biggest source of uncertainty, has been the maintenance of constant lamp current. A transistorized current regulator has been developed which now permits lamp currents up to 10 amps to be held constant to about 1 part in 10^5 over periods of an hour or more.

(*b*) *Optical Properties of Diffusing Media.*—In order to provide basic data required for industrial colour control, experiments on the optical properties of pigment suspensions have been continued, and it is now well established that the colour of well-dispersed pigment mixtures can be predicted accurately by theory based on isotropic scattering. Since many industrial problems arise from incomplete dispersion of the pigments, the effect of dispersion on reflectance is also under investigation. A small, laboratory-scale pigment-dispersion mill developed especially for this work has given excellent dispersions of titanium oxide in glycerine. Equipment has also been developed for measuring independently the colour and turbidity of slightly turbid media such as gelatine.

9. OPTICS.

(Division of Physics.)

(*a*) *Optical Image Quality.*—A number of laboratories have recently developed equipment for measuring the quality of optical instruments in terms of contrast transfer functions; these refer to the reduction in contrast produced by the instrument for each sine-wave Fourier-component in the object. The Division is experimenting with equipment using interference fringes as the test object; as the interferometer is adjusted, these fringes change spacing, the image is scanned photoelectrically, and the contrast transfer function recorded.

Such measurements provide the best assessment of an optical instrument in respect of its performance, but the results must be related to the lens aberrations to be of direct use in lens design. A nodal-slide interferometer has been constructed for comparative measurements of the aberrations of microscopes and short-focus camera lenses.

(*b*) *Astronomical Optics.*—The limit of the fine detail that can be photographed successfully with telescopes is set by "seeing" disturbances in the Earth's atmosphere. A simple photoelectric instrument has been constructed to monitor the quality of a solar image, and it is now being mounted on a 5 in. photoheliograph to limit automatically the taking of photographs to periods of good seeing. An allied problem is the control of seeing conditions within large optical instruments; some progress has been made in this direction. The 1/8 Å filter, intended for observing the fine structure of a solar chromosphere, has been under construction for some time. A trial assembly has revealed a number of necessary modifications which are now being incorporated.

10. SOLAR PHYSICS.

(Division of Physics.)

The work of the Division of Physics on solar physics is described in Chapter XXVIII., Section 2.

XXV. ELECTROTECHNOLOGY.

1. GENERAL.

With the steady growth in Australian secondary industry electrical and electronic instrumentation has an increasingly important function. For the calibration of electrical equipment the Division of Electrotechnology is responsible for the maintenance of the Commonwealth Standards of measurement of electrical and magnetic quantities. It maintains the Commonwealth standard of measurement of frequency in conjunction with the Commonwealth Observatory, Mount Stromlo, and other standards derived from frequency, resistance, and electromotive force. The Division undertakes electrical and magnetic measurements on materials, and the calibration of instruments and equipment such as resistors, bridges, potentiometers, capacitors, inductors, indicating instruments, instrument transformers, signal generators, wavemeters, and fluxmeters.

The work of the Division of Electrotechnology is reported in this chapter, together with that of the Electrical Research Board, established in collaboration with the Electricity Supply Association of Australia to encourage research in electrical engineering within the universities (see Section 7).

Division of Electrotechnology.—The programme of investigation within the Division has continued without major change. Research is continuing on the dielectric properties of insulating materials and the microwave spectra of gases, and to improve and extend electrical measuring and standards facilities.

During the year a general conference on electrical standards and measurements was held at the National Bureau of Standards, Boulder, Colorado. A paper was presented by the Division describing recent work on calculable capacitors. In collaboration with the National Bureau of Standards another paper was presented describing the application of these advances to the absolute measurement of capacitance.

2. Direct Current.

(Division of Electrotechnology.)

(*a*) *Primary Electrical Standards*.—The electrical units are not arbitrary like the metre, kilogram, and second, but are defined uniquely in terms of them by the laws of electromagnetism. The basic electrical standards must then be pieces of equipment whose electrical properties can be calculated from their dimensions. These calculable standards are then used to calibrate other standards in the more convenient form of resistance coils and standard cells which must be stable enough to preserve the units in the intervals between such absolute determinations.

When completed the work on calculable capacitors (see Section 4 (*a*)) will enable the Division to undertake its own absolute determination of the ohm. At present it is necessary to rely on calibrations by other national laboratories of the Division's primary group of coils and cells. Their stability is such that intercomparisons at intervals of two or three years are sufficient to maintain units to within one part in 1,000,000 relative to overseas standards.

Six resistance coils of American manufacture have been received after selection and calibration by the National Bureau of Standards. These coils, together with ones recently calibrated by the National Physical Laboratory, have enabled an intercomparison to be made of the values of the ohm as maintained by Great Britain, the United States of America, and Australia. The intercomparisons yielded results consistent to considerably better than one part in 1,000,000. If the new coils continue to give consistent results they will be incorporated in the Australian primary group.

(*b*) 1-100 *Ohm "Build-up" Resistor*.—A second report been received on the special 1-100 ohm "build-up" resistor presented by the Division to the Bureau International des Poids et Mesures. The resistor has proved very satisfactory for both the 1-100 ohm "build-up" and also for obtaining an accurately known 1 : 10 ratio.

(*c*) *Low Frequency Measurements*.—Many of the problems of precision resistance measurement could be simplified by the use of low frequency alternating current rather than direct current. To investigate this technique, equipment has been constructed for the measurement of resistance over a wide range of frequencies down to 1 radian/sec.

Preliminary measurements of 10 ohm, 100 ohm, and 1,000 ohm standard resistors show differences of less than one part in 10^7 between the A.C. and D.C. values for frequencies below 10 radians/sec., using special bifilar-type A.C. resistors for reference purposes.

3. Power Frequency.

(Division of Electrotechnology.)

(*a*) *Power Supplies for Higher Frequencies*.—Many electrical installations, particularly in aircraft, use power supplies of relatively high frequency (e.g., 400 and 800 c/s). To provide a calibration service at these frequencies the first requirement is a stable source of power with low distortion. Two power amplifiers have been installed, each with a power output capacity of 700 watts and a frequency range from 30 to 5,000 c/s. A special generator has been developed to drive these amplifiers. It is a novel resistance-tuned two-phase transistor oscillator giving exceptional stability in frequency and voltage output together with extremely good waveform.

(*b*) *New Electrostatic Voltmeter*.—An advanced stage has been reached in the development of a precision electrostatic voltmeter in which no elaborate scale or optical system is required. Its deflections are determined indirectly by measuring the capacitance between the fixed and moving plates. The instrument itself is quite small and as it need not be visible or directly accessible its mounting and installation are comparatively simple.

(*c*) *Current Transformer Testing*.—The majority of current transformers have rated primary currents of 5 amperes or greater, but 1 ampere and even ½ ampere are common and occasionally transformers with rated currents as low as 100 mA or less are employed for special purposes.

For testing this type of transformer it is convenient to use the classical absolute method employing resistors in series with primary and secondary windings. A resistance box has been constructed for the purpose containing a number of precise four-terminal non-inductive resistors. The unit includes a small fan for forced air cooling and with this in operation the errors in ratio and phase difference between the various resistors are each less than three parts in 100,000. Transformers with currents between 5 amperes and 50 mA can be tested with it.

(*d*) *High Voltage Measurements*.—The crossed cylinder form of measuring spark gap has distinct advantages over the more usual sphere gap. Tests up to the available limit of 140 kV indicate the possibility of a very convenient type of gap with relatively short cylinders. Full-scale tests are necessary on a large gap at high voltage where the advantages of this design would have greatest significance.

(*e*) *Pinholes in Insulation*.—In the course of manufacture pinholes may ocur in the solid insulation used to cover wires or cables. Usually they are detected electrically by inducing electrical breakdown through the pinholes as the insulated wire is drawn through a liquid bath.

A method has been developed in which the bath is replaced by a cloud of ionization arising from bare wires raised to a potential of some tens of kilovolts and spaced a few inches from the insulated wire under test. In the absence of a pinhole the current flowing to the wire is very small, e.g. 0.01 μA, but on the arrival of a pinhole the current increases to about 20 μA, which is easily detected and can be made to operate an alarm or counter.

(*f*) *Transistors*.—Transistors are continually finding fresh applications and they have been employed to good effect in several instruments recently developed in the high voltage laboratory, notably in a new tuned detector amplifier for use at 50 c/s.

4. Audio and Radio Frequency.

(Division of Electrotechnology.)

(*a*) *Calculable Capacitor and Absolute Determination of the Ohm*.—Major research effort continues in development of a calculable capacitor and its use in the absolute determination of the ohm. The significance of this work lies in the development of a new type of capacitor whose capacitance in electrostatic units is computable to a much greater accuracy than is the inductance of the more usual form of calculable inductor. In recent years the velocity of light has been determined very accurately indeed by several workers and this makes it possible to take full advantage of such an improved electrostatic standard as the basis for establishing the standard ohm, which is by definition an electromagnetic unit.

(i) *Calculable Capacitor.*—The calculable capacitor, which was described in detail in last year's report, is ready for use as a standard but awaits the completion of the associated capacitance bridge equipment before actual absolute determinations can be made. Various minor improvements will be carried out in the meantime and subsequent changes may follow from the detailed testing to take place when the bridge equipment is ready.

Improvements carried out since the previous report include:—The re-design of the electrical circuits supplying the electromagnetically controlled shield tube; the incorporation of a constant deviation monochromator in the optical system; the coating of all glass-air surfaces with anti-reflection films; and the building of the mercury isotope lamp into a single unit with its 250 Mc./s power supply using a design kindly supplied by the National Physical Laboratory, England.

(ii) *Absolute Determination of the Ohm.*—To relate a 1-ohm D.C. resistance standard to a 0.25 pF calculable capacitor several different measuring techniques must be used. These include the intercomparison of nominally equal small capacitances, the determination of the ratio of two capacitances, the measurement of resistance in terms of capacitance and frequency, the determination of the frequency coefficient of resistors, and the comparison of resistors using direct current. To take full advantage of the accuracy attainable with the calculable capacitor very stable components and precise measuring assemblies are required. The components, capacitors and resistors, should have a short-term stability of 1 in 10^7, necessitating a temperature coefficient of 1 in 10^6 or less if very precise temperature control is to be avoided. The measuring assemblies must have a sensitivity of 1 in 10^7, or better, and all errors must be evaluated to this order.

Capacitors.—The capacitors, which range in value from 0.25 pF to 5,000 pF, are all three-terminal, sealed and filled with nitrogen. It is not difficult to establish the design principles which lead to successful capacitors, but much experimental work is required to apply them successfully in practice. A low temperature coefficient may be obtained by using materials with a low coefficient of thermal expansion such as invar and quartz, or by compensating temperature changes by using materials of different temperature coefficients. These components are being developed and a number of the more successful designs constructed. The larger capacitors are compensated parallel-plate assemblies and the smaller values mostly cylindrical.

Resistors.—Resistors of low temperature coefficient have been constructed using an alloy whose temperature coefficient of resistance can be varied by heat treatment. Bare wire is wound on a grooved glass former and the temperature coefficient is adjusted by heating for controlled periods at about 400° C. One-thousand-ohm coils for the construction of a 100-10,000 ohm "build-up" resistor are being made in this fashion and a number of A.C./D.C. transfer resistors have been made with the same alloy.

Techniques.—A considerable amount of work has been necessary to obtain a sensitivity of 1 in 10^7 or better in each measurement. A special low-noise preamplifier and integrating indicator has been constructed to improve the sensitivity of the alternating current measurements. The direct current sensitivity has also been improved by careful balancing of the galvanometer, by shielding it from convection currents and electrostatic fields, and by the use of a photo-transistor amplifier and recorder to amplify and display the deflections of the galvanometer.

Measuring techniques based on the use of special transformers as precise ratio devices have been investigated in some detail to discover the limitations of the transformers themselves and the associated circuits. A special power amplifier with an adjustable negative output impedance has been constructed to energize these transformers, so that the harmonic content of the secondary voltages is less than 0.1 per cent. Another type of feedback amplifier has been used to multiply the input impedance of an inductive voltage divider by about 100. This is particularly useful in extending the low frequency limit of such a divider.

Improved temperature-controlled cabinets have been constructed to speed the testing of components. The temperature may be controlled in the range 20-50° C. to better than 0.1° C. Lower temperatures may be obtained if a supply of cold water is available.

(*b*) *Frequency Measurements.* (i) *Frequency Standard.*—Two new oscillators using Essen ring crystals are now in operation. Each crystal is mounted in an oven controlled in temperature to about 0.001° C. by means of temperature-sensitive resistors and a transistor amplifier. The oscillator maintaining amplifier has a gain of 10^5 and variations to be expected in this amplifier should not cause frequency changes greater than 1 in 10^{11}. Short-term comparisons of the two oscillators show frequency variations of ± 5 in 10^{11}. These variations are attributed to the effects of mechanical vibrations on the crystals. Equipment has been constructed to record continuously the frequency difference between the 16 kc./s G.B.R. transmission from Rugby, England, and the 16 kc./s derived from one of the Division's oscillators. The G.B.R. transmissions are monitored by the N.P.L. in terms of a caesium atomic beam standard. In this way the Division's frequency standard can be related to the caesium standard with far greater accuracy than by reference to astronomical time standards.

(ii) *Microwave Frequency Measurements.*—When high frequencies are generated from a 100 kc/s standard by using several stages of multiplication and harmonic selection, the resulting signal progressively deteriorates until a frequency is reached at which it is useless for precise measurements. To extend the frequency range higher a system is being developed in which the starting point for multiplication is a 10 Mc/s crystal oscillator. A special beam deflection tube is used to lock this oscillator to the mean frequency of the 100 kc/s standard but at the same time isolates it from any cycle-to-cycle variations arising in the standard.

(*c*) *Impedance Standards for Very High Frequencies.*—Precise coaxial lines with high conductivity have been developed as impedance standards for very high frequencies. Carefully controlled electroplating has been used to bring the conductors accurately to the required dimensions and uniformity throughout their length. The work has been assisted by the use of precise air gauging equipment developed by the Division of Metrology. This equipment measures simultaneously the diameters of the inner and outer conductors of a coaxial line, and indicates characteristic impedance directly.

Errors of centring the inner conductor with respect to the bore of the outer conductor must also be small. An audio frequency eccentricity tester has been developed which indicates the displacement directly when the lines are assembled.

(*d*) *Impedance and Attenuation Measurements at Microwave Frequencies.*—The facilities available for impedance measurement in the 9,000 Mc/s waveband have been extended, and additional equipment has been purchased for use in the 8 and 12 mm bands.

A standard attenuator is being constructed for the calibration of attenuators in the radio frequency and microwave ranges, and most of the components requiring precise machining have been completed. Special ring gauges and an air gauge head are being made by the Division of Metrology to permit calibration to the required accuracy.

(*e*) *Standard Source for Microwave Noise Measurements.*—A radiometer consisting of a sensitive microwave receiver, switched alternately to compare the radiation from two sources at different temperatures, has been built experimentally as the forerunner of equipment for the calibration of noise sources and for other measurements at low signal levels.

The switch used in the present radiometer has no moving parts and depends for its operation upon rotation of the plane of polarization of the incident waves by a ferrite rod in an applied magnetic field.

A standard noise source has been designed for use in conjunction with the radiometer. This consists of a matched waveguide heated electrically and standardized at the temperature of the melting point of gold.

(*f*) *Absolute Calibration of Electromagnetic Indicating Instruments.*—A theoretical investigation of the forces developed in variable-parameter electrical networks has been made to relate the deflecting force in a class of square-law measuring instruments to the applied voltages or currents. For certain special cases, and for networks that are almost loss-free, simple results in terms of terminal impedance or admittance parameters have been obtained.

(*g*) *Calibration of a Slotted Line by Capacitance Measurement.*—The refined techniques of capacitance measurement developed in the Division have been used to calibrate directly the pick-up probe of a radio frequency slotted line. Tests at 300 Mc/s have shown that a comparatively crude slotted line can yield accurate results when calibrated in this manner.

(*h*) *Microwave Spectroscopy.*—Studies of the microwave spectra of the isotopic water molecules HDO and D_2O have been made near 10,000 Mc/s, by using a high-resolution spectroscope with a resolving power of about 500,000. The complicated hyperfine structure observed has now been completely analysed with the assistance of the digital computer SILLIAC, and the experimental results interpreted in terms of the magnetic and electric properties of the hydrogen and deuterium nuclei.

It became necessary to calculate the shape of an absorption line that results when both Doppler effect and pressure broadening have to be taken into account. An extensive tabulation was carried out of this line shape, the so-called *Voight profile.*

(*i*) *Random Noise.*—The statistical properties of some basic random processes are being investigated both theoretically and by experimental methods; in particular a process obtained by smoothing a random square wave with a resistance capacitance method. The random square wave is generated from a sequence of pulses arising from the passage of gamma particles through a liquid scintillator. A random square wave generator of this type, with associated smoothing network, constitutes a very versatile noise generator in the video frequency range, amplitude probability distributions being obtainable ranging from binomial to Gaussian by the adjustment of a single circuit element.

Probability distributions and other statistical properties of this smoothed random square wave have been deduced by theoretical means and measured experimentally using the multi-channel probability distribution analyser and associated equipment. Distributions have been studied of maxima, minima, samples taken at random, and the time interval between adjacent crossings of various amplitude levels.

5. MAGNETICS.

(Division of Electrotechnology.)

(*a*) *Magnetic Test Bench.*—Some of the most important properties of magnetic materials are those determined from tests for normal induction, D.C. permeability, and hysteresis. These tests are usually done on samples in the form of bars or strips in a D.C. permeameter. This comprises a magnetic yoke of low reluctance, suitable exciting coils, and special clamps for holding the specimen in position. Associated with it are a stabilized power supply, current control circuits, search coils for measuring the induction in the specimen, magnetometers for measuring field strength and field gradient, fluxmeters, and ballistic galvanometers.

A test bench has now been designed embodying this equipment and incorporating a number of refinements and instrumental techniques. An interesting visual aid included in the equipment is a light indicator showing the magnetic state of the material progressively on a diagrammatic hysteresis loop.

The test bench includes means for calibrating fluxmeters and ballistic galvanometers using the flux linkage generator described below.

(*b*) *Flux Linkage Generator.*—This instrument makes use of the well-defined saturation properties of "rectangular-loop" magnetic materials to generate a flux linkage which is insensitive to the precise value of the magnetizing current.

An improved battery-operated flux linkage generator has now been completed in which the flux linkage is quite insensitive to the magnetizing current. The errors of the new instrument are well within the limits ± 0.05 per cent. ± 40 maxwell-turns.

6. DIELECTRICS.

(Division of Electrotechnology.)

(*a*) *Crystal Growth.*—Work has continued on the problem of growing large single crystals. Using the Kyropoulos method several large crystals of sodium chloride and of potassium chloride either pure or containing deliberately added impurity have been grown.

Attempts have been made to grow single crystals of aliphatic compounds by lowering the molten material slowly through a sharp but very stable temperature gradient (Bridgman method). Whilst no crystals suitable for dielectric measurements have been produced much progress has been made in determining the conditions favorable for the growth of good-quality crystals.

(*b*) *Alkali Halides.*—When a divalent ion of the same size replaces the positive ion in the lattice of an alkali halide an equal number of positive ion vacancies are introduced. A dipole is formed if the impurity, possessing an extra positive charge, and the cation vacancy, possessing an effective negative charge, are associated on nearest lattice sites. The intensity of the dielectric absorption is directly proportional to the number of pairs of impurity ion and vacancy present. This provides a reliable measure of the degree of association existing in the crystal. In the past, information was obtainable only from D.C. conductivity measurements. As the association has only a second order effect on D.C. conductivity, deductions made previously are of doubtful accuracy. Using samples cleaved from single crystals the dielectric absorption has been studied as a function of impurity concentration and of heat treatment for calcium in sodium chloride. At room temperature most of the impurity present is associated with vacancies in groups more complex than an isolated pair.

(*c*) *Aliphatic Long-chain Compounds.*—Attention has been concentrated on the radio frequency absorption which is due to rotation of the molecules around the long axis. Earlier investigations showed that the equilibrium positions of the molecules are appreciably different in energy and there was evidence that these differences are associated with the interaction between the ends of the molecular chains.

In solid solutions of long-chain dipolar compounds in long-chain hydrocarbons this interaction at the ends of the polar molecules should be small when they are shorter than the solvent molecules. Dielectric measurements have been made with systems of this type containing ketones and ethers as the polar molecules. The energy differences between the equilibrium positions of the polar molecules under these circumstances are very small.

The ratio of the magnitude of the dielectric absorption in relation to the crystal structure indicated that in these solutions all the polar molecules contribute to the dielectric absorption, and that each polar molecule possesses two positions of equilibrium approximately equal in energy and opposite in direction.

The usual rate process parameters were also determined for the solid solutions. As in pure dipolar compounds, the frequency factors and energy barriers increased in a linear fashion with molecular chain length. However, the frequency factor, and hence the entropy of activation, associated with any particular energy barrier were smaller than in the pure dipolar compounds.

Dielectric absorption caused by crystal imperfections may be removed by annealing, and the kinetics of this process are being examined.

7. Electrical Research Board.

The electrical research Board was established by the Organization in collaboration with the Electricity Supply Association of Australia to foster fundamental electrical research in the universities and to assist graduates of special ability to undertake post-graduate research. The Board makes grants to support specific research projects being developed in the universities.

The membership of the Board is representative of the Electricity Supply Association of Australia, the universities, and the Organization. The funds of the Board are derived from contributions made by member establishments of the Electricity Supply Association of Australia, and grants have now been made to most of the universities in the Commonwealth.

The Board has recently received several contributions to its funds from electrical manufacturing firms, and it is hoped that there will be a steady increase in the number of contributors from this field of industry. An invitation has been issued to the Federal Council of the Electrical Manufacturers of Australia to nominate a representative to become a member of the Board.

Grants made by the Board for the current year include: A grant to the Electrical Engineering Department, University of Tasmania, for research on non-linear circuit theory; a grant to the Department of Physics, New England University, for investigations on arc electrode phenomena; a grant to the Electrical Engineering Department, University of Adelaide, to continue the project on network analysers; grants to the Electrical Engineering Department, University of Sydney, for research on the design of an analogue digital conversion accessory and the design of circuits in A.C./D.C. convertors; a grant to the Electrical Engineering Department, University of Queensland, to continue the project on the protection of electrical plant against lightning; and a grant to the Department of Electrical Engineering, University of Melbourne, to continue with the project on power system stability using models.

With the aid of special funds contributed by the Electricity Supply Association of Australia, the Board has been enabled to sponsor the establishment of a new laboratory at the University of Queensland to develop high voltage research. Equipment has been ordered from Europe and it is anticipated that by the end of 1959 this will be installed and in operation in the new building being provided for this purpose by the University of Queensland.

XXVI. RADIOPHYSICS.

1. General.

Electronics has assumed increasing importance in the various fields of science and technology. Both industry and science now widely employ electronic instrumentation and methods. Radio and radar in particular, with the use of higher frequencies and pulse methods, have provided unique research tools previously unavailable.

The Organization's Division of Radiophysics carries out research in those fields in which modern radio techniques have particular application. These include such studies as rainmaking and radio astronomy, which are new sciences developed with the aid of electronics. The Division's programme also includes a study of physics of semiconductors, transistors, and their application to electronic circuits; the development of radio aids to aerial navigation; and work on the transmission of radio waves.

The Organization and its predecessor have undertaken researches on the ionosphere and the propagation of radio waves since 1927, and this work has contributed much to knowledge of the upper atmosphere. Many of these investigations have been undertaken by or under the auspices of the Radio Research Board.

The Radio Research Board has now ceased to undertake research with its own staff, but continues to sponsor approved radio research projects in the universities. The staff formerly employed by the Board in Sydney has now been transferred to the Department of Electrical Engineering, University of Sydney, and the research projects undertaken by this group are being continued under grant from the Board.

The Board's research group at Camden, New South Wales, has now become the Upper Atmosphere Section and is engaged on studies of the outer environment of the Earth.

The Organization's Consultative Committee on Radio Research co-ordinates research in radio being undertaken by the universities, the Postmaster-General's Department, the armed services, and the Organization.

The work of the Division of Radiophysics is outlined in Sections 4, 5, and 6 of this Chapter, and in Chapter XXVII., Section 8, and Chapter XXVIII., Section 3. That of the Upper Atmosphere Section is described in Sections 7 and 8 of this Chapter.

Division of Radiophysics.—Four large-scale practical rainmaking experiments are currently in progress, to establish the extent to which rainfall in typical areas of Australia may be increased by cloud seeding with silver iodide from aircraft. These experiments are located in the Snowy Mountains region, the mid-north of South Australia, the Northern Tablelands of New South Wales, and the Darling Downs, Queensland.

The highlight in radio astronomy has been the acceptance of a tender for Australia's giant radio telescope. This will have an aerial 210 feet in diameter and is to be erected near Parkes, New South Wales.

The Chief of the Division, Dr. E. G. Bowen, visited Great Britain and the United States of America on two occasions during the year to expedite completion of the specifications and the calling and acceptance of tenders for the giant radio telescope. He also participated in a symposium on weather modification, held at Shenandoah, Virginia, in May, 1959.

At the international symposium on radio astronomy held in Paris in 1958, and at the 10th General Assembly of the International Astronomical Union, the Division was represented by Dr. J. L. Pawsey and other senior officers. Dr. Pawsey was Chairman of the Organizing Committee of the Symposium.

Upper Atmosphere Section.—A programme of research has been initiated this year on the outer atmosphere, and observations have commenced on radio noise and hydromagnetic waves in this region.

As Chairman of the Upper Atmosphere Research Committee of the Academy of Science, the Officer-in-charge was responsible for co-ordination of Australian work during the International Geophysical Year on the tracking of earth satellites and the planning of upper atmosphere research with rockets at Woomera.

During the year the Officer-in-charge paid brief visits to Japan and the United States, leading a session of an international symposium on fluid mechanics and the ionosphere at Cornell University, and participating as an Australian delegate in the work of the United Nations Committee on the Peaceful Uses of Outer Space.

Following the death of Sir Douglas Mawson, the Officer-in-charge was elected Chairman of the Australian Academy of Science National Committee of Antarctic Research, and took part in the international meeting at Canberra of the Special Committee for Antarctic Research of the Council of Scientific Unions.

2. Cloud and Rain Physics.

(Division of Radiophysics.)

This work is reported in Chapter XXVII., Section 8.

3. Radio Astronomy.

(Division of Radiophysics.)

This work is reported in Chapter XXVIII., Section 3.

4. Radio Propagation.

(Division of Radiophysics.)

Work has continued on the survey of atmospheric radio noise levels throughout Australia at the wavelengths used for broadcasting and high-frequency communication. This is a co-operative venture, with contributions from several members of the Consultative Committee on Radio Research which brings together the principal organizations in Australia using radio communications and those engaged in radio research.

During the year a further station has been set up, completing a network of three stations in tropical latitudes. In addition to these routine observations a series of shorter-term investigations has been carried out at another station. The latter experiments are designed to provide information which will facilitate the application of the survey results to actual communication design problems.

The Division recently organized an informal conference on directions of arrival of high-frequency radio waves. Dr. H. A. Whale of Auckland University College described the results of his recent work in this field and the problems of Australian communication organizations were discussed.

5. Radio Navigation.

(Division of Radiophysics.)

The flight testing of the bearing measuring equipment has continued. A new design of aerial tested at Kingsford Smith Airport, Sydney, was free of significant error. Radials and orbits flown with the equipment installed on a Royal Australian Air Force Dakota indicated a bearing accuracy of better than ± 2°.

Tests were conducted with the ground equipment located on the top of the control tower at Hobart Airport, Tasmania. The accuracy of the equipment was affected by the severe reflections obtained from the surrounding hills. Errors of up to 5° were then obtained for short intervals and errors of 2·3° could be expected for the majority of the tracks flown.

The results were considered to be marginal by the Department of Civil Aviation. The Hobart site could not be considered exceptionally unfavorable, and it has been decided to carry out another set of flight tests at Katoomba or Canberra, after the development of an indicator more suitable for the cockpit presentation of the bearing information. One design of cockpit instrument has been completed and a suitable site at Katoomba has been selected.

The Department of Civil Aviation has, again, shown interest in this work and provided a contribution to the cost.

6. Semiconductors and Transistors.

(Division of Radiophysics.)

The Division is investigating basic physical properties of semiconducting materials, and the techniques required for producing them with the special characteristics needed for the construction of devices, such as transistors and variable-reactance diodes. Sample quantities of diodes have been constructed for use in parametric amplifiers. The application of transistors in electronic circuits is also being investigated.

(*a*) *Semiconductor Physics.*—A special crystal-grower has been developed and used for growing crystals of potassium chromicyanide, for tests in maser amplifiers. The crystal-grower operates with the solution at constant temperature and has produced a number of large crystals of volume up to 25 c.c.

Diodes developed for use in parametric amplifiers have been mainly of alloy junctions of small area, and gold-bonded types. Progress has been made in the fabrication of junctions by "thermal bonding". A low-inductance resilient contact has been developed which allows the diodes to be cooled to liquid air temperatures.

(*b*) *Transistor Circuit Development.*—Design of a Mk. II. model of the transistor airborne distance measuring equipment is virtually complete and three sets are now being assembled. One will be used as a production prototype and the other two will be used by the Division.

The equipment is designed to operate from a 115 volt-400 c/s supply, and provides 48 channels and a digital type of distance indicator of improved accuracy. Crystal control of the local oscillator frequency has been incorporated in the 224 Mc./s receiver. Solid state switching devices, which have become available recently, will replace the thyratrons in the modulator, but two valves are still retained in the transmitter. Components are mounted on printed wiring boards which are assembled into seven modules each 6½ in. by 4½ in. by 2½ in.

A programme is being undertaken of environmental, reliability, and flight testing of the equipment.

7. Ionosphere.

(Upper Atmosphere Section.)

(*a*) *Airglow.*—The distribution of airglow brightness over the night sky was recorded during 1958 by means of a photometer lent by the United States National Bureau of Standards. Most of the observations were of the red oxygen emission at a wavelength of 6,300 Å. The intensity was strongly correlated with magnetic activity and during one aurora the airglow was observed to be polarized. The sense of the polarization and subsidiary considerations indicated that the aurora was excited by an electric field perpendicular to the geomagnetic field. This is believed to be the first time that this has been observed.

(*b*) *Backscatter Sounder.*—The sounding of the properties of the ionosphere over an area with a radius of 4,000 km. from Camden was continued during the year with the I.G.Y. backscatter sounder. On many occasions echoes were returned from patches of ionization aligned along the Earth's magnetic field.

(*c*) *Forward Scatter.*—An investigation into the forward scatter technique of radio communication was begun in January, 1959, in collaboration with the Postmaster-General's Department. Forward scatter communication is a method of transmitting information by radio over distances of the order of 1,000 km., and is largely unaffected by the ionospheric conditions which interrupt ordinary radio traffic.

The forward-scatter link is being operated between Hobart and Camden. At the Camden end the extensive antenna system was installed by the Post Office on a site made available by the University of Sydney. The preliminary data obtained have shown that this method of communication is reliable and simple to operate.

(*d*) *Magnetometer.*—A magnetometer lent by the Australian National University was installed in March, 1959. It has provided, for the first time, detailed information of the correlation between magnetic variations and bursts of low frequency radio noise generated in the outer atmosphere of the Earth.

(*e*) *Sporadic* E *Ionization, Spread* F *Region, and the Scintillations of Radio Stars.*—These phenomena have excited the attention of radiophysicists for one or two decades. The first is responsible for unusual radio propagation at high frequencies, the second for anomalous scattering of radio waves, and the third is a limiting factor in the accuracy of measurements in radio astronomy. Much is known about the times and places of occurrence of these phenomena but their origins have remained a mystery until now. During the year theoretical work in the Section has provided what may prove to be the solution of these problems. It has been found that the under surfaces of the ionized regions become unstable at times when the ionization is drifting upwards under the electrodynamical forces associated with local electric currents whose form and magnitude are known from ground observations. Under such conditions small irregularities in ionization such as are produced by turbulence and meteors become magnified into large inhomogeneities which cause scattering. The times and places of occurrence of these phenomena agree well with the theoretical predictions.

8. Outer Atmosphere.

(Upper Atmosphere Section.)

The outer atmosphere may be considered to extend from the top of the ionosphere at about 400 km. out to about 50,000 km. from the Earth. In this region, which as recently as six years ago was thought not to differ from interplanatary space, complex interactions occur between streams of charged particles from the Sun, the magnetic field of the Earth, and the ions normally present. These result in the generation of radio waves, hydromagnetic waves, trapped radiation belts, aurorae, and many other phenomena, some of which can be observed from the ground.

(*a*) *Radio Waves from the Outer Atmosphere.*—Using a technique for suppressing radio interference previously used in cosmic noise observations, it has been found possible to record continuously bursts of radio noise in the frequency band from 2 to 40 kc./s. The occurrence of the bursts is strongly correlated with magnetic and auroral activity. On a few occasions the amplitude of the noise at 4.6 kc./s and the intensity of the red oxygen airglow showed the same detailed variations, providing for the first time evidence that the radio noise originates in the upper atmosphere.

A number of extended characteristic and reproducible patterns of noise variation or noise storms which were associated with aurorae were discovered.

A spectrum analyser for studying the frequency distribution of the noise was constructed and several different classes of noise spectra were identified.

It has been shown theoretically that the noise bursts may be caused either by the gyration of charged particles about the field lines of the geomagnetic field at a distance of the order of 30,000 km. from the Earth, or by the emission of shock electromagnetic waves (Cerenkov radiation) by particles approaching the ionosphere.

(*b*) *Hydromagnetic Waves in the Outer Atmosphere.*—It has been known for many years that it is possible to observe small sinusoidal variations of about one part in 100,000 of the Earth's magnetic field. It is now believed that some of these are caused by string-like vibrations of the field, and that their study will lead to new data on the outer atmosphere. Apparatus for recording these oscillations has been built and installed at Townsville, Camden, and Hobart. A theoretical study has shown that some anomalies in the observed oscillation periods may be removed if harmonics are taken into account.

XXVII. ATMOSPHERIC PHYSICS.

1. General.

The Organization has several research groups working towards a better understanding of the physics of the atmosphere. An adequate knowledge of weather transformations has become increasingly important with the development of modern techniques for air transport, agriculture, and other scientific activities requiring meteorological information. The Organization's research aims at a basic study of the processes controlling atmospheric effects, and improvement in weather forecasting. Also, since Australia is the driest of the continents, attention is directed to both the supply and conservation of water.

The Organization's major meteorological investigations are undertaken in the Division of Meteorological Physics at Aspendale, Victoria, and are directed to knowledge and use of the science of meteorology on the widest basis.

The Division of Radiophysics is engaged on a series of experiments in cloud physics and artificial rainmaking, which have now reached the stage of full-scale regional trials to assess whether rainfall can be increased significantly over a given target area.

In the Chemical Research Laboratories, research is in progress on techniques to retard evaporation of water from dams and other storages. Again in full-scale field trials these investigations have shown that even on large areas of water, losses from evaporation can be very much reduced.

Investigations undertaken by the Division of Meteorological Physics are dealt with in Sections 2-7 of this Chapter. The work of the Division of Radiophysics on rainmaking is described in Section 8 of this Chapter. The work of the Chemical Research Laboratories on anti-evaporation of water is described in Chapter XVII., Section 5 (*a*). In Chapter XVII., Section 5 (*c*) is reported the work of the Chemical Research Laboratories on ice nucleation in relation to methods for artificial rainmaking.

Division of Meteorological Physics.—The main fields of activity of the Division have continued unchanged. The position of Officer in Charge of ozone research has remained vacant throughout the year.

Officers of the Division have continued their service on various working groups of the World Meteorological Organization, on commissions of the International Meteorological Association, and on national committees set up by the Australian Academy of Science.

The Division also continued its association with other international activities in the field of meteorology including the International Geophysical Year (I.G.Y.).

The Division has collaborated with a number of other establishments on meteorological problems, including the Divisions of Plant Industry and Land Research and Regional Survey; the Victorian Horticultural Research Farm, Scoresby; the Antarctic Division; the State Electricity Commission of Victoria; and the Postmaster-General's Department.

2. DYNAMIC METEOROLOGY.

(Division of Meteorological Physics.)

The I.G.Y. has stimulated further work in meteorological problems of Antarctica. The theory of Antarctic katabatic winds developed in 1956 was extended. Minor topographic features can produce large spatial variations, while the movement of depressions along the coast can cause considerable temporal variations of the katabatic wind strength.

Influences of the elevated cold source prevailing in Antarctica, on the climate and circulation patterns in middle southern latitudes, are an important problem for Australia. Experiments were made using a removable model "Antarctica" in a rotating vessel containing water heated at the periphery and cooled in the centre. Although complete dyamic similarity was not attainable, results are significant for an understanding of southern hemisphere temperature régimes.

In conjunction with the Department of Meteorology, University of Melbourne, surges at the rim of Antarctica were studied in relation to seasonal and aperiodic variations in the zonal flow strength in middle latitudes. Lag correlations were found, of possible value in forecasting seasonal anomalies, but a more complete quantitative treatment must be made of the underlying exchange processes. A study is being extended to the southern hemisphere of periodic mass redistributions based on data covering the whole of the northern hemisphere, with emphasis on the polar regions.

Further work is being undertaken on the Antarctic cold source in conjunction with a longer-term programme assessing the effects of summer-time heating on large-scale flow patterns in Australasia. An estimate of the partial heat source below 10,000 feet due to long-wave radiation has been completed. Continental heating affects synoptic weather sequences. Cool changes during summer in south-eastern Australia are influenced by convection and the large-scale sea-breeze circulation which penetrates well over 100 miles inland. An expedition to obtain detailed information on penetration yielded results from Renmark (South Australia) interesting in relation to similar phenomena around the Australian hinterland. Largely because of their bearing on fire control, these phenomena have been treated statistically in a separate publication.

The heat balance and dynamics of the horizontal circulations over and near Australia require a slow transverse drift transporting the energy. Storage of energy in certain forms is important in assessing spontaneous increases of the circulation, producing monsoonal rains. These processes, which might prove significant in predicting the onset of the monsoonal régime, are being studied theoretically and by using data from Australia and South-East Asia. Related to this problem is the study of prominent subsidence inversion over Australia which bears on the density of pollutants and on radio-wave propagation. Theoretical predictions have been confirmed concerning the control of the inversion height by surface heating, and a diurnal oscillation of height up to 1.5 km. has been found in central Australia.

3. MICROMETEOROLOGY.

(Division of Meteorological Physics.)

Solar energy becomes the motive power of weather phenomena on all scales through the radiative and turbulent energy exchanges between ground and atmosphere. One of these exchanges, i.e., evaporation, is of outstanding importance. The Division has continued studies of these processes and also of the friction between air and ground—the brake on the atmospheric "engine".

A prototype instrument has been developed to measure directly the turbulent flux, embodying automatic computation from the inputs of suitably responsive anemometers, fine-wire resistance thermometers, &c. In field tests the net energy so determined has agreed with the amount available from radiation. If this agreement is maintained, results should accrue in far greater number than have been available anywhere in the past. While primarily designed to measure daytime evaporation from natural ground surfaces, the instrument will also be valuable in studies of heat and momentum transfer. Field trials of a simpler, portable, transistor version ("Evapotron") will begin soon.

The sensitive integrator designed for the above work has been adapted to other applications, notably in the integration of daily solar radiation. Several such instruments have been supplied to other Divisions for various agricultural and pastoral investigations.

A modified form of cup anemometer has been developed which uses transistor circuitry to provide remote recording of wind speed. Unlike existing instruments, it is well suited to record very low speeds.

Temperature and wind speed profiles in the lower atmosphere have been studied in relationship to turbulent transport of heat and momentum. Observations, from both this Division and other sources, have been unified. This is a cornerstone investigation on which most meteorological and agricultural applications rest, and the latest result, combined with an earlier one on heat transfer, should change accepted thinking.

For five months of summer an evaporation survey was made of Lake Eucumbene, the largest storage of the Snowy Mountains Hydro-electric Scheme, from which a routine method was recommended for evaluating evaporation. Knowledge of this loss will be significant in operating the reservoir for best water utilization. Over land, advance has been made in calculating evaporation from measurements of wind speed and humidity at two heights.

In the study of exchanges between sea and atmosphere, results obtained on cruises of F.R.V. *Derwent Hunter* are being analysed. A new approach has been made theoretically to the measurement of turbulent transfer, via structure functions, and this should be more suited to shipboard application than existing methods.

4. AGRICULTURAL METEOROLOGY.

(Division of Meteorological Physics.)

Progress has been made with lysimeter installation for study of water losses from bare soils and from crops. Ten of the twelve 6-ton soil containers are now in operation and a year's observations have accrued from seven. One lysimeter is now installed on the special recording balance built in the Division. The balance has a resolving power equivalent to an evaporation of 0.001 in., and has performed satisfactorily over a lengthy test period. This weighing lysimeter also gives the amount of dewfall by night. The next three balances have reached the assembly stage. Auxiliary equipment has been constructed for controlled uniform irrigation and for observing relevant micrometeorological and soil factors.

Observations relating to the infestation of tobacco by blue mould were maintained throughout the summer in collaboration with the Division of Plant Industry and the Victorian Department of Agriculture, and will be continued. It may be possible to predict critical meteorological conditions at the leaf surface from measurements of ambient climate in the crop. The onset of dew on a freely exposed thin lamina is being studied as a related problem.

An instrument has been developed for the estimation of the amount of dew on natural grass. The sensitivity of the instrument appears to depend on the general length of the grass, but it is hoped to overcome this difficulty.

In the field of evaporation and micrometeorology, apparatus has been constructed for other research establishments, and instruction and general assistance given on a number of problems.

5. Radiation.

(Division of Meteorological Physics.)

For the measurement of net radiation at the Earth's surface, a new weatherproof and sensitive radiometer has been developed and is to be manufactured commercially under licence. Instruments have already been supplied to various users.

Measurements at night on the change of radiative flux with height in the lowest few metres above the ground have shown that radiation is more effective in cooling these air layers than had previously been supposed on theoretical grounds.

Co-operation has been maintained with the State Electricity Commission of Victoria in studying the effect of aluminium powder on the heat transfer from a cooling pond.

6. Ozone.

(Division of Meteorological Physics.)

The Dobson spectrophotometer at Macquarie Island was destroyed by fire during the year, but ozone measurements for international collation have continued throughout at Melbourne and Brisbane.

7. Miscellaneous Investigations.

(Division of Meteorological Physics.)

Practical meteorology in Australia suffers from the scarcity of information from the ocean areas to south and west. The feasibility has been assessed of weather buoys, transmitting pressure in the first instance. Difficulties include radio transmission and direction finding, and these are being investigated.

At the request of the Division of Land Research and Regional Survey, a recorder was designed capable of a year's unattended operation. It can provide information on water level, rainfall, temperature, &c., and should have wide use, particularly for hydrological work in remote regions. It is undergoing stringent field tests.

Measurements of radio-activity in rainfall near Melbourne were commenced in 1958 as a contribution to the I.G.Y. Weekly samples are taken and the total radioactivity determined, using an ion-exchange resin technique. Radio-active decay of the sample enables the date to be estimated of the test explosion responsible, providing information on transfer processes between equatorial regions (where the explosions have occurred) and higher latitudes.

A radar station, using service types of radar, is being constructed at Aspendale as a meteorological research instrument. Designs are now complete and assembly has begun.

Assistance was given to the Postmaster-General's Department in estimating temperature changes likely in the underground coaxial cable to link Melbourne and Sydney.

Data on wind fluctuations at heights from 40 to 500 feet above ground have been supplied to the Civil Engineering Department of Bristol University. Calibration services for anemometers and radiation instruments have continued for outside bodies.

8. Cloud and Rain Physics.

(Division of Radiophysics.)

Investigations of physical processes in the formation of cloud and rain were initiated in the Division in 1947, following the demonstration that certain clouds could be induced to rain by seeding with dry ice. The initial objective—a sound background for assessment of this potentially important discovery—has largely been realized. Current work includes large-scale practical rainmaking trials designed to establish the extent to which artificial rainmaking can be expected to increase precipitation in typical areas of Australia.

Rain occurs naturally by one of two physical processes: by ice crystal formation in supercooled clouds and by the coagulation or coalescence of water droplets in clouds which are warmer than freezing. Minute dust-like particles in the atmosphere (" nuclei ") play a vital part in initiating both types of rain. By supplying substitutes when naturally occurring nuclei are absent or ineffective, rain can be induced artificially. Current work on rainmaking has been devoted mainly to large-scale cloud seeding using the most effective artificial freezing nuclei yet discovered (namely, crystals of silver iodide). The nature and occurrence are also studied of the natural freezing nuclei responsible for initiating the rain-forming process in supercooled clouds. Physical processes in clouds are still imperfectly understood and studies of cloud structure continued.

(*a*) *Cloud Formation and Properties.*—Cumulus clouds contain much less water than would be expected from the simple adiabatic model of cloud growth, and a theory has been developed accounting for this discrepancy. This suggests that dry air from above growing cloud tops is engulfed by them. The cloud droplets evaporate, cooling the air and causing it to sink. These parcels of dry air may penetrate downwards to considerable distances. Equipment has been developed for mounting in aircraft to study the fine structure of cumuli, and the first flight programme has been completed. Observations were made at different levels in many clouds and much data collected. Analysis of this information has commenced.

A chemical diffusion method has been developed to measure those nuclei in the air which promote condensation at slight supersaturations and which are important for cloud formation. Differences in stability of clouds and their ability to precipitate may be caused primarily by differences in the nucleus content of the air in which they form.

(*b*) *Natural and Artificial Freezing Nuclei.*—Naturally occurring freezing nuclei are thought to be dust particles having the property of producing ice crystals in supercooled clouds of water droplets. Measurements of their concentration have been confined to a few readings per day because of the time involved. Isolated counts may not always be representative of actual concentrations and a continuously operating automatic cold box has been developed to overcome this deficiency. This samples air at a faster rate than is possible with manual equipment and, over a period of six months, has provided measurements 75 per cent. of the time. Short-lived peaks in concentration (of the order of 8 hr. duration) have been found to occur which are sometimes but not always correlated with changes in wind speed or direction. Diurnal trend has also been discovered with a maximum about noon.

An additional instrument of this type is being built for investigating the source of nuclei and determining size ranges of those that are effective.

Study continued of ice crystal nucleation and a theory developed of the activity of silver iodide as an ice crystal nucleus. The effect is now understood of size distribution of smoke particles produced by silver iodide burners, as also is the de-activation of silver iodide particles by sunlight.

This has made possible specification of the output of an ideal burner with which practical burner outputs can be compared. This model has served as a criterion for evaluation of improvements made by modifications to the burners now in use. Activities and decay rates of smokes so far tested have been in substantial agreement with the predictions of the theory.

Properties have been studied of silver iodide dispersions produced by spraying a solution of silver iodide in liquid ammonia. This dispersion method may yield a greater number of nuclei active at temperatures above —10° C. than burning of acetone solution. A greater seeding rate can be achieved if desired. Decay rates of particles produced by the two methods seem comparable. A flight test of this method has been planned.

9. ARTIFICIAL STIMULATION OF RAIN.

(Division of Radiophysics.)

The programme in the artificial stimulation of rain covers three phases: stimulation of rain over large areas; seeding of individual clouds; and investigations of the processes involved. Most effort has been devoted to the first phase. Experiments are in operation, extending from South Australia to Queensland, in which silver iodide smoke is released from aircraft into clouds to determine the effect on the rainfall over areas of 1,000-3,000 square miles. Aircraft used have included two Cessna 310B's and one Anson belonging to the Organization, and a Lockheed Hudson belonging to East-West Airlines. The Anson was disposed of during the year, and a Beechcraft Twin Bonanza chartered from East-West Airlines for these projects. Seeding of individual clouds and other experiments have been carried out in a DC-3 aircraft of Detachment "B" of the Aircraft Research and Development Unit (A.R.D.U.) of the R.A.A.F.

(*a*) *Large-Scale Cloud Seeding.* (i) *The Snowy Mountains Experiment.*—The Snowy Mountains experiment was continued in co-operation with the Snowy Mountains Hydro-electric Authority, and has been in operation for four consecutive winter seasons (suspended during the summer). Clouds over a "seeded" area of about 1,000 square miles are seeded with silver iodide smoke from the Hudson aircraft; there is a small "target" area in the middle of the "seeded" area. Precipitation in these areas is compared with that in an adjacent "control" area. The seeding season is divided into periods of about two weeks and during the whole of any one period clouds over the target area may or may not be seeded, the choice of whether or not to seed being made on a random basis. The relation between the natural rainfall in the target and control areas is determined during the unseeded periods.

In seeded periods there has, on the whole, been more rain in the seeded and target areas than would be expected, judging by rain in the control area. The magnitude of the increase has been 12 and 19 per cent. for the seeded and target areas respectively. The statistical significance of these results has been computed in a number of ways, some of which were developed for the purpose. Increase in the target area is almost certainly due to seeding (probability being 94-98.8 per cent. depending on the type of test) while that in the seeded area is most probably so (90-98 per cent.). The experiment will continue during the 1959 winter season, and then be terminated, since construction works are being started in the seeded area and increases of rain there are not desired.

(ii) *South Australian Experiment.*—The second large-scale experiment is in South Australia, in two areas each of about 1,000 square miles in the hills north of Adelaide. Clouds over one or the other of the two areas are seeded for a period of about two weeks with silver iodide smoke released from an aircraft, choice of the area to be seeded being made on a random basis. This procedure should increase ease of detection of the effects of seeding compared with that used in the Snowy Mountains experiment, where only one area is seeded on an on/off basis. The South Australian experiment, which is restricted to the winter months, commenced in April, 1957. In the first season there was a drought and few clouds suitable for seeding appeared. In the second season there were more clouds and more seeding; for neither year, however, did seeding have any effect. The experiment is continuing for a third winter season and its future will then be decided. A negative result in one region is not inconsistent with a positive one in another (e.g. the Snowy Mountains experiment) since differing geographic factors may be important. During the past year all the seeding for this project has been carried out by one of the Division's Cessna 310B aircraft.

(iii) *New England Experiment.*—An experiment similar to that in South Australia commenced in New England in February, 1958, in two areas of 2,000-3,000 square miles centred respectively on Tamworth and Inverell. This experiment runs all the year round except for November and December, when it is suspended in the interests of the wheat harvest. The first year's operations, assessed on the basis of 130 rain gauges already in existence, appear promising; substantial rainfall increases have accompanied seeding but the results are not statistically significant. For the second year the Weather Bureau has installed 240 rain gauges to provide a more complete picture of rainfall reaching the ground.

A Cessna 310 aircraft has been used on this project but a Beechcraft, chartered from East-West Airlines, will be used after June, 1959. The experiment will continue for some years.

(iv) *Darling Downs Experiment.*—A new experiment similar to that in New England has been started in the Darling Downs of Queensland, in two 2,000-3,000 square mile areas centered on Warwick and Dalby. It will run from December 15th to May 30th each year, and continue for several years. The first year's operation has been completed. Operationally everything appeared satisfactory but no rainfall results have yet been received. One of the Cessna aircraft was used.

(v) *Warragamba Catchment Experiment.*—In co-operation with the Sydney Water Board an experiment is being organized over the catchment area of the Warragamba Dam, a major storage for Sydney's water supply. Seeding will start in July, 1959, when an appropriate network of rain gauges has been installed. The experiment will be similar to those above except that the seeding period will be of one day's duration. This is much shorter than in the other experiments because it is desired to analyse separately effects of seeding in easterly and westerly situations, both of which bring rain to this area.

(vi) *Corella Catchment Experiment.*—In cooperation with Rio Tinto Construction & Development Pty. Ltd., further cloud seeding has been carried out over the Catchment area of the Lake Corella Dam, which was built to provide water supplies for the mining operations at Mary Kathleen. The objective was to help fill the dam. No control data are available for assessment of results of seeding, but clouds were seeded, rain fell, and at the end of the season the dam was nearly full.

(*b*) *Stimulation of Individual Clouds.* (i) *Amount of Silver Iodide.*—Individual clouds are being seeded with silver iodide smoke to determine the relation between number of freezing nuclei supplied and amount of rain stimulated. A DC-3 aircraft of Detachment "B" of A.R.D.U. is fitted with two silver iodide burners producing freezing nuclei at a different rate. A cloud is selected and seeded with either the large burner, small burner, or no burner at all, on a random basis. The quantity of rain which falls is determined by suitable instruments as the aircraft flies through the cloud. Flight trials have commenced, and so far nine satisfactory seedings have taken place, but further results will be necessary before conclusions can be drawn.

(ii) *Electrostatic Charges.*—Seeding clouds with silver iodide may cause changes in the electrostatic field around the cloud. Apparatus to measure these changes has been developed and fitted to the DC-3 aircraft used in single-cloud experiments.

(iii) *Radioactive Tracing Method.*—Apparatus has been developed for detecting gamma rays from airborne particles which are radioactive, to study cloud structure and mass air movements. This apparatus has also been fitted to the DC-3 aircraft used in single-cloud experiments.

(*c*) *Freezing Nucleus Production.* (i) *Aircraft Generator.*—A new type of silver iodide smoke generator for use on aircraft was developed last year and has now been tested and introduced into service. It is self-contained, and smaller and lighter than the previous type. Brief tests in flight have been made, and more exhaustive tests in the laboratory; the freezing nucleus output per gram of silver iodide burnt, and also the rate of decay, are similar to the older type.

(ii) *Lead Iodide.*—A preliminary test was made using lead iodide freezing nuclei which, according to some theories, should have a lower decay rate than silver iodide nuclei. Nuclei were produced by burning a solution of lead iodide in a burner designed for silver iodide, and detected in an aircraft which flew downwind from the burner; zinc sulphide was used as a tracer. The results were scattered but decay rate appeared just as rapid as for silver iodide.

XXVIII. EXTRATERRESTRIAL PHYSICS.

1. General.

Australia has played an important role in the development of radio astronomy, a new science which has emerged almost entirely since the end of World War II. Following the discovery that heavenly bodies emit radio as well as light waves, radio astronomers, working side by side with scientists using optical methods, have been able to reveal a new understanding, not only of the Sun and planets of our own solar system, but also of our Galaxy, and of the innumerable galaxies beyond. The radio telescope has set new boundaries to space, far beyond those at the limit of optical vision. In addition, study of the 21 cm. spectral line of atomic hydrogen has yielded a new conception of the distribution and nature of matter pervading interstellar space and the transformations which this matter undergoes in the creation of heavenly bodies.

Radio astronomy has formed a major part of the research programme of the Division of Radiophysics (see Section 3 of this Chapter). Studies of the ionosphere are carried out by the Upper Atmosphere Section (see Chapter XXVI., Sections 7, 8). Work on solar radiation is carried out by the Division of Physics (see Section 2 of this Chapter).

2. Solar Physics.

(Division of Physics.)

The solar physics programme is aimed at studying the solar photosphere and chromosphere and their fine structures, the nature of the various solar disturbances, and the physical laws responsible for their types of behaviour. This work has acquired greater importance because of the current widespread investigation of the outer layers of the Sun and of interplanetary space with radio, rocket, and satellite techniques, for the many unexplained and unexpected phenomena in the corona and interplanetary space almost certainly have their origins close to the Sun's surface.

High resolution observations have continued of photospheric granulation and sunspots. It has been confirmed that the granules last much longer than was generally believed. They display very little change in brightness or size during their lifetimes (about 10 min.). In sunspots also, special techniques have now revealed granular structures even at the centre of the umbra.

While it is generally accepted that photospheric granulation represents the top of the Sun's outer convection zone, the stability of the individual granules, coupled with observations made in Australia and elsewhere revealing their cellular structure, raises the question of whether these layers may not be more in the nature of quasi-stable convective, rather than fully developed turbulent, regions. Again, if umbral granules also have a convective origin, the problem arises as to how strong motions occur in these regions of high magnetic field.

Though the interpretation of granule observations is still controversial, some relevant progress has been made by developing the theory of radiative transfer in a form applicable to non-uniform media since, in principle, this enables the structure of a medium to be deduced from its appearance.

Observations of the chromosphere have been continued in connexion with the International Geophysical Year programme. This has involved a cinematographic search for flares occurring during sunlight hours, a programme of considerable international importance because of the scarcity of solar observing stations in these longitudes.

3. Radio Astronomy.

(Division of Radiophysics.)

The radio telescopes already developed by the Division have been used throughout the year to study radio emissions from the Sun, our Galaxy, and more distant galaxies. A prefabricated parabolic "dish", 60 feet in diameter, has been obtained from the United States of America and is being mounted, in alt-azimuth fashion, on a structure designed by the Division.

An area of 416 acres has been purchased at Parkes, New South Wales, for the 210 feet diameter Giant Radio Telescope. Constructional work on the instrument should commence during 1959 and be completed during 1961.

Two officers of the Division, Dr. J. L. Pawsey and Dr. C. S. Gum, have been acting on a subcommission of the International Astronomical Union with two Dutch astronomers, in revising the system of galactic co-ordinates to bring it into closer accord with present knowledge of the shape of the Galaxy. The choice of the new co-ordinate system was based almost entirely on radio observations, particularly on the hydrogen line observations. This is the first time that a major astronomical decision has depended primarily on radio data.

(*a*) *Radio Waves from Beyond the Solar System.* (i) *Results from the 3.5 Metre "Mills Cross".*—The results of observations made with the 1,500 feet cross aerial have now been reduced and tabulated. These comprise a catalogue of several thousand discrete sources of radio emission in the southern and part of the northern sky. In addition to these "radio stars", the background radiation has been observed and plotted in the form of contour diagrams of radio brightness.

Two interesting features of radio stars are their identification with visible objects and their distribution in space. Many new possible identifications of radio sources with faint galaxies have been made, and these are important in showing which types of galaxy are strong or weak radio emitters. From the statistical properties of radio sources the majority lying within our own Galaxy are probably remnants of supernova explosions which occurred in the distant past. Some sources which appear to lie outside our Galaxy and should, therefore, be of small angular size are surprisingly large. These may be truly extended sources or, alternatively, blends of two or more sources. The latter possibility could account for past discordances between the results of surveys using different kinds of instrument.

The contours lying in the Milky Way reveal spiral structure agreeing in form with that shown by optical and radio H-line studies.

The emission plot from the direction of the local "supergalaxy", a group of external galaxies, suggests that this radiation is from our own Galaxy and not, as previously believed, from external galaxies.

On the instrumental side, the original 85 Mc/s. cross has been modified (by the addition of a remote aerial with a radio link) to operate as a widely spaced two-aerial interferometer. This equipment is capable of measuring angular sizes of radio stars in the range 10 sec. to 1 min. of arc. A comprehensive survey is now in progress of the southern sky.

(ii) *Observations with the 15 Metre Wavelength Cross Aerial.*—The collection and analysis of records made in the direction of the Milky Way have continued and are nearing completion. The results will be presented in the form of a contour map, covering a strip about 10° wide along parts of the galactic equator. In contrast to the corresponding map at 3.5 m. (which shows a bright ridge with many individual brighter sources along the galactic equator), the 15 m. map shows a comparatively dark (low intensity) trough with many isolated darker patches. These dark patches coincide in position with optically bright regions of ionized hydrogen, the darkness resulting from the fact that this gas partially obscures the background which—at 15 m. wavelength—is much brighter than the hydrogen gas. In many cases the distances of these gas clouds are known, and a combination of optical and radio data make it possible to distinguish the local from the more distant features of the radio Galaxy.

The 15 m. cross aerial has also been used to study ionospheric refraction effects. At this comparatively long wavelength, refraction must be taken into account when determining the positions of the radio stars; conversely, if radio stars of known position are observed, the measured displacement of these sources may be used to determine ionospheric parameters. Records of some of the stronger radio sources have been analysed and the results combined with those of vertical incidence soundings of the ionosphere made by the Ionospheric Prediction Service. Over quite a long period of time the total electron content of the ionosphere was directly proportional to the square of the critical frequency. This surprisingly simple result was found to be consistent with other estimates of total electron content.

(iii) *The Spiral Structure of our Galaxy.*—The line radiation emitted at a wavelength of 21 cm. from interstellar neutral hydrogen can be used to study the large-scale structure of the whole Galaxy, or for detailed investigations of particular interstellar gas clouds.

A narrow strip of sky around the Milky Way has special importance for large-scale structure studies. An extensive survey of the southern part of this strip has already been carried out with the Division's 36-ft. paraboloid reflector and the detailed results are at present being published. As a similar survey has been carried out for the northern sky by the Leiden Observatory, the whole Milky Way has now been covered with approximately the same resolving power.

These results provide an approximate picture of the spiral structure of our Galaxy. A new analysis is being undertaken which is based on a new derivation of the rotational motions of the Galaxy, these motions being used to provide a distance scale used for interpreting the hydrogen line observations.

The new hydrogen line receiver, in which the frequency band is split into 48 separate channels, has been used for observations of two particular regions: the shape and motions have been studied of a large cloud complex in Orion and Taurus, and the position of a cloud of neutral hydrogen in Pyxis has been compared with the distribution of nearby ionized hydrogen. These investigations have demonstrated the high information-gathering possibilities of this receiver, and a survey is being made covering the whole visible sky at a low resolving power. This will give a general picture of the hydrogen distribution over the sky, before commencing observations of the regions of greatest interest with a larger radio telescope.

(*b*) *Solar Radio Waves.* (i) *The Crossed Grating Interferometer.*—The 64-aerial crossed grating radio heliograph has been used to scan the Sun. The aerial beam is 3 min. of arc wide and by repeatedly scanning the surface of the solar disk it allows a map to be produced daily showing the distribution of radio brightness.

The bright regions, "radio plages", which are the source of the slowly varying component of solar emission, have brightness temperatures of about 1,500,000° C. This result, and the absence of any marked circularity in the polarization of the emission, leave little doubt that the emission is thermal, from high-density regions in the corona. This confirms the Division's earlier theory of the emission.

Similar radio heliographs have been developed in Japan, the United States of America, and France. These operate on different frequencies (and thus record radio waves emitted from different levels in the solar atmosphere) but the results may be usefully combined with those from the 20 cm. instrument. By collaborating with observers in these countries a study of one particular plage has been made possible and the electron densities deduced at various levels. The region of excess density extends from about 20,000 to more than 300,000 km. and the gas radiates at a temperature of about 2,000,000° C., emitting not only radio waves but X-radiation strong enough to affect the ionosphere.

To obtain greater detail of the Sun's atmosphere, elaborate observations were made during the partial eclipse of April 1959, of radio emission from the whole uneclipsed surface of the Sun and from small areas viewed by the grating interferometer.

(ii) *Solar Radio Disturbances at Metre Wavelengths.*—Investigation has been intensified of bursts of radio emission from the Sun. The radio spectrograph, in operation since 1952 in the wavelength range 1.4-7.5 m., has been extended to 1.4-12 m. so that the tracks of solar corpuscles may be followed to greater heights in the corona.

The swept-frequency interferometer, built for locating the sources of solar bursts at different frequencies, has been extended and improved and facilities incorporated for automatic computation of positions. This device has operated daily in the wavelength range 4.3-7.5 m. and has tracked the sources of radio bursts of spectral type III. The sources move outward at velocities higher than were previously suspected, the average velocity being about half that of light. The nature of the disturbance is closely associated with streams of relativistic electrons ejected from solar flares.

Other results with the interferometer support current theories that certain types of emission originate in plasma oscillations while others are due to synchrotron radiation.

Spectral investigations have been concentrated on the newly recognized spectral types. One of these, the type IV. burst, is a prolonged period of enhanced radio continuum which occasionally follows type II. bursts, and occurs only when a flare of major importance is observed optically. Close correlation exists between type IV. bursts and geomagnetic storms two days later. This might provide a basis for a prediction service for magnetic storms which disrupt communications on Earth. Another new spectral type (V.) has been isolated, correlated closely with other solar emissions occurring at centimetre wavelengths.

Using a part of the 15 m. cross aerial in a novel way, it is possible to locate the sources of solar radio bursts with useful accuracy and so deduce that the level of origin of 15 m. bursts is about 2.9 solar radii from the centre of the Sun.

Editing has continued on world-wide observations on solar radio emission for the *Annals of the International Geographysical Year* and for the *Quarterly Bulletin of Solar Activity.*

(*c*) *Receiver Techniques.*—Limit to the sensitivity of radio receivers, at frequencies greater than a few hundred megacycles per second, is usually set by the internal noise generated within the receiver. After several decades of comparative lack of progress in receiver techniques, two new types of " low noise " amplifier have appeared which promise a reduction in internal noise of one or two orders of magnitude. These are the " maser " (microwave amplification by the stimulated emission of radiation) and the " parametric amplifier " or " mavar " (mixer amplification by variable reactance); the Division is investigating both types.

(i) *Masers.*—A maser receiver for use at 1,400 Mc/s. is being developed in collaboration with the Division of Physics, using ruby as the active maser material. The ruby is placed inside a cavity which is resonant at both 1,400 and 11,000 Mc/s. The power required for amplification is supplied by a radio frequency oscillator at 11,000 Mc/s., which is known as the " pump ". The apparatus must be cooled to liquid helium temperatures to obtain sufficient gain to overcome incidental losses in the cavity and the leads.

A convenient figure of merit for maser amplifiers is the product of bandwidth and square root of their gain ($G^{\frac{1}{2}}$ x B), which is constant for cavity masers. The first amplifier developed had a figure of merit of 2 x 10^6 at a temperature of 4° K; this was improved to 7 x 10^6 in a second model; and a figure of 2 x 10^7 Mc/s. is expected with a cavity of reduced size in which almost complete filling with ruby is possible. Improvement on this figure is unlikely at 1,400 Mc/s. without adopting a travelling-wave type of device. Preliminary investigations have begun of suitable slow-wave structures.

(ii) *Parametric Amplifiers.*—The variable reactance elements used have been semiconductor diodes. As for the maser, power is supplied by a radio frequency " pump " at a frequency (f_p) higher than that of the signal to be amplified (f_s). The amplified output signal can be taken at any of three frequencies: at the input signal frequency (f_s); at the difference frequency ($f_p - f_s$); or at the sum frequency ($f_p + f_s$).

One amplifier has been constructed for operation at 85 Mc/s. It has a pump frequency of 170 Mc/s. and a noise figure of 1.35. An " up-converter " for use at 250 Mc/s., pumped at 9,170 Mc/s. and with the output taken at the sum frequency, 9,420 Mc/s., is being developed.

(*d*) *Theoretical Studies in Cosmical Electrodynamics.*—A study of the interplanetary magnetic field has been completed. The essential feature of the model is that the magnetic field extends radially from the Sun, and on occasions past the Earth's orbit. The field is created from solar magnetic fields when ionized gas is ejected from the Sun's atmosphere. Study of radio bursts at that time reveals details of the gas motions.

The interplanetary model differs radically from earlier models and alone appears capable of explaining the main features of observed cosmic ray variations. Cosmic rays are deflected by the field and some even trapped in the field, causing effects measurable on the Earth. Large quantities of lower energy particles are also trapped, and this may be significant in connexion with similar particles recently found in our outer atmosphere by rocket exploration.

It is encouraging that radio refraction measurements overseas indicate a solar magnetic field which is radial to at least 20 solar radii.

A logical extension of the study of the interplanetary field and gas is the theory of magnetic storms, aurorae, and associated effects. This theory has stagnated for some years, partly for lack of knowledge of the modes of transmission of the disturbances through the atmosphere. It is known that the " solar wind " disturbs the geomagnetic field at distances of several Earth radii; the problem has been to trace the inwardly moving electromagnetic disturbance to the Earth's surface where its effects are measured. This has now largely been solved, use being made of the most recent atmospheric data from satellite observations. The essential feature of the theory is that the atmosphere must be treated as two co-existing gases—a neutral atom gas and a fully ionized plasma. These move, to some extent, independently, and in the very high atmosphere entirely independently.

This transmission problem has stimulated further interest in magnetic storm theory, resulting in a new theory of the main phase of a storm, according to which the outermost parts of the Earth's field are inflated by the solar gas and then blown away to form a " tail " behind the Earth. Incidental effects explainable by this streaming field model include the Gegenschein, a patch of light in the night sky almost opposite the Sun. These ideas will be tested by actual measurements from rockets.

Several problems have been solved in radio emission, propagation, and absorption. The theory of emission of irregular clouds of ionized hydrogen has been extended to explain some radiation coming from outside the solar system. The theory of emission by electrons gyrating in a magnetic field has been extended to give estimates of harmonic radiation. The emission from organized groups of electrons by various mechanisms, the Cerenkov, gyro, and synchrotron processes, has been studied. Large increases in intensity are possible.

Methods have been developed of ray tracing in a magnetoionic medium. These can be important in the interpretation of some signals from satellites and rockets.

XXIX. MATHEMATICAL STATISTICS AND MATHEMATICS.

1. General.

The Organization maintains a separate Division of Mathematical Statistics to provide workers in the various Divisions and Sections with specialized help in planning their researches and analysing their experimental results (see Section 2 of this Chapter).

Work on mathematical instruments and mechanical and electrical methods of computation is undertaken in the Section of Mathematical Instruments (see Section 3 of this Chapter).

Division of Mathematical Statistics.—There has been intensification of work undertaken in collaboration with other units of the Organization, and as a result, the Division is now associated with practically every research activity of C.S.I.R.O.

A detailed survey has been made of the Organization's requirements for digital computing. Special features requiring consideration are (*a*) the widespread development of automatic recording of scientific data specifically intended for treatment by digital computers, (*b*) the diverse types of computing required, and (*c*) the geographical distribution of C.S.I.R.O. These can be met most satisfactorily by an integrated system involving several small computers distributed in certain capital cities, and a large central data-processing installation.

Extensive development has taken place with regard to digital computing itself. During the year 1958-59 nearly seven times as much was carried out for C.S.I.R.O. on

CSIRAC at the University of Melbourne as in the previous year. Mr. T. Pearcey, co-designer of CSIRAC, after a period in the United Kingdom, has returned to Australia and transferred from the Division of Radiophysics to the Division of Mathematical Statistics, to work on CSIRAC and collaborate with the staff of the Computation Laboratory, University of Melbourne.

In Adelaide, the Weapons Research Establishment of the Department of Supply continued to provide facilities for a large-scale climatological study, by allowing the Division regular computing time on their rostered programme for the use of WREDAC and its ancillary equipment.

Sir Ronald Fisher, F.R.S., the leading statistician in the United Kingdom, joined the Division to work with the staff as Senior Research Fellow for six months, spending most of the period at Divisional head-quarters in Adelaide. The principal object of his visit was to give a course of lectures and seminars in scientific inference.

The Chief attended the International Biometric Conference held at Ottawa in August-September, 1958, and subsequently visited the leading statistical laboratories of the United Kingdom and the United States.

In addition to co-operative investigations within the Organization, and the provision of advisory assistance to an increasing number of outside bodies, including universities, and Commonwealth and State Departments, the Division has continued its own programme of research in various theoretical aspects of mathematical statistics having important practical applications.

Mathematical Instruments Section.—This Section, situated in the Electrical Engineering Department of the University of Sydney, has combined to co-operate with that department in the development of a general-purpose digital computer now undergoing performance tests.

Dr. M. W. Allen, who was primarily responsible for its design and development, has now resigned to take up an academic appointment at the University of Adelaide.

2. MATHEMATICAL STATISTICS.

(Division of Mathematical Statistics.)

The following is a summary of research projects completed or in progress.

(*a*) Research has been continued on evaluation of a certain class of integral arising in distribution problems of multivariate analysis, using zonal functions of the irreducible components obtained in representing the real linear group on the polynomials in the elements of a positive definite matrix. Particular cases have been solved using the method, and work is proceeding on generalization of the solution.

(*b*) Progress has been made in research on estimators in multiple linear regression analysis.

(*c*) Some years ago, an asymptotic expansion was developed for expressing a percentile deviate of a non-normal variate, in terms of the corresponding normal deviate. This expansion has been found useful, either for calculations of higher accuracy in the case of functions already tabulated (especially for values outside their range, and for tables of multiple entry to supply intermediate values more accurate than can be obtained by interpolation), or for cases where no tables yet exist. Further terms have now been added to the expansion, thus increasing its accuracy to a very high degree.

(*d*) Progress has been made on basic Monte Carlo procedures for use with digital computers. Routines have been developed for generating random rectangular, triangular, and normal deviates; exhaustive testing and tabulation of these routines is proceeding. It is expected that they will lead to considerably increased efficiency in the use of digital computers for Monte Carlo techniques.

(*e*) The various laws advanced to provide a quantitative formulation for the influence of nutrient environment on plant growth have been critically analysed. Promising results have been obtained, and research is continuing.

(*f*) A long-range study has been initiated of the control of bacterial infections in hospitals. Extensive hospital records are being examined for changes in resistance of various bacterial strains to each of a number of antibiotics.

(*g*) Research continued on interpolation of monthly rainfall in terms of the position and altitude of observing stations, and an investigation has now been completed giving interpolates of high accuracy.

(*h*) Following successful analysis of intercorrelations of monthly rainfall in South Australia, the scope of the work has been extended to include a large portion of the south-eastern section of the continent, stretching from Eyre Peninsula to western Victoria, and applied to the rains of a much smaller time interval, namely, six days. Results so far obtained confirm the findings of previous work. An important new result is a well-defined annual oscillation in the axis of maximum correlation.

3. MATHEMATICAL INSTRUMENTS.

(Mathematical Instruments Section.)

The construction of "Snowcom", a small general-purpose computer to meet the specification of the Snowy Mountains Hydro-electric Authority, is now complete, and the machine is undergoing final adjustment and operational testing.

The Authority has a need for computing facilities, both for planning and for operation of its hydro-electric scheme. After a careful examination of the Authority's requirements, it was decided to develop a general-purpose transistorized, stored-programme, digital machine with a magnetic drum store and with punched-tape input and output, based on the logical design described by Stanley P. Frankel. The machine has a storage capacity of over 2,000 words, each equivalent to 10 decimal digits, with provision for extension.

Although the computer was developed specifically to meet the needs of the Snowy, it was envisaged from the start that a transistorized computer of the type planned could be made very small and reliable and would consume negligible power; also that it might be produced and marketed in small numbers at a reasonable cost, bringing it within the range of many research establishments.

"Snowcom" is now complete and is being subjected to various operational test routines, prior to transfer to the Authority's head-quarters in Cooma.

XXX. RESEARCH SERVICES.

1. LIBRARIES.

During the year new accommodation has been provided for the libraries at the Divisions of Building Research, Textile Physics, and Soils—in the latter case this involved setting up the Divisional library for the first time. In addition the Sheep Biology Laboratory at Prospect, the Soil Mechanics Section at Syndal, and the Cunningham Laboratory at Brisbane acquired new library premises.

Progress was made in compilation of the first stage of a loose-leafed union catalogue of scientific serials representing up-to-date holdings in Australian libraries. It is interesting to note that, because of the availability of this catalogue, the nature of many written enquiries received at Head Office has already changed. Emphasis centres now largely on searches for material known not to be available in Australia, and these should ultimately result in filling gaps in existing scientific and technical holdings. Exploratory work began on a union catalogue of monographs, and this project may later be combined with the proposed National Union Catalogue, to be housed at the National Library in Canberra, and on which work will commence in 1960.

Institutes, Government establishments, and private industry all responded well to a questionnaire distributed for revision of the Directory of Research Establishments in Australia. Rapid progress is being made in this revision.

The coverage of the Australian Science Index and C.S.I.R.O. Abstracts and List of Translations continues to expand.

2. TRANSLATION.

The Translation Section has carried out translation, written and oral, as required by Divisions and Sections of the Organization. An additional facility has been use of a recording instrument to supply recorded translations on plastic disks in cases where this solution was deemed adequate and where an instrument (or a substitute playback) was available at the Division or Section concerned. In these cases translation has been greatly accelerated. Requests for translation, following a general trend, have increased by some 6 per cent. over that for the previous year.

The Section has operated as Australian agent for the Index of Translations of the British Commonwealth Scientific Office, and has also supplied microfilm copies of all its translations from Russian to the United States Office of Technical Services.

The languages now being handled within the Section are German, Dutch, Swedish, Norwegian, Danish, French, Italian, Spanish, Portuguese, Russian, Ukrainian, Polish, and Czech, and, in some fields, Rumanian.

3. ENGINEERING SECTION.

The Engineering Section is engaged in research and development in specific engineering fields. One of its interests lies in control of environment. Development of plant-growth cabinets and other special facilities for the Canberra phytotron is a major current activity (see Chapter I., Section 18). Work continued on solar energy research and on development of precise equipment for measurement and control of temperature and relative humidity. In agricultural engineering, progress was made in investigation of certain basic processes, mainly related to wheat production. To assist in this work novel techniques have been developed to apply digital computer processes to analysis of experimental data.

(*a*) *Phytotron Project.*—A number of naturally lit plant-growth cabinets of different types have been constructed, to enable full-scale engineering and biological tests to be carried out in Canberra. To house these cabinets and to form a prototype of the glass-house portion of the phytotron building, an experimental glass-house section of novel design has been erected there. Necessary services have been installed to enable the glass-house and its cabinets to be operated as a true prototype, and comprehensive data have been obtained on various aspects for inclusion in the final design. Stability has been established in the glass-house structure by subjecting it to internal pressure to simulate the worst wind pressures likely to be encountered in service.

The phytotron design requires that the fifteen glass-house sections should be maintained at a series of controlled temperature levels throughout the year. To provide winter heating and summer cooling for this purpose, a heat-pump bench unit has been designed and is in process of development. It is proposed that this unit will draw heat in winter from a pond and reject it there in summer when acting as a cooler. The pond will also store heat removed by refrigeration systems from the plant-growth cabinets, and, in conjunction with the heat pumps, will greatly simplify and cheapen transfers of heat from one part of the installation to another.

One of the leading features of the Australian phytotron will be flexibility of operation and ability to provide simultaneously a variety of temperatures and length-of-day regimes. For this purpose it has been necessary to develop a multi-pole programme switch to enable the time of transition of each compartment from day to night conditions to be preset readily and accurately. A prototype of this switch is at present under test at Canberra.

Artificially lit cabinets of different types will be included in the phytotron by using high-intensity fluorescent lamps now available overseas. Supplies of these lamps are being obtained, and development of the cabinets has commenced.

(*b*) *Solar Energy.*—Performance of the Section's solar water heater has been further investigated to study variations in orientation and optimum angles of inclination for different criteria. Orientation is not particularly critical, especially in latitudes less than 30°, where deviations up to 45° from due North are permissible without serious effect on performance. Inclination can similarly be varied to alter the summer/winter collection ratio without greatly affecting total annual absorption of energy.

The many enquiries still being received on solar heating indicate that there is widespread general interest in this subject. Solar absorbers manufactured to the Section's design are now available commercially in all States; and in northern areas, where economic advantages are greatest, they are becoming increasingly popular. Their introduction on a large scale, however, is unlikely until their cost can be reduced. Alternative materials and methods of construction are being examined with this in view.

In the normal solar water heating system, water is circulated between heater and storage tank by thermosyphon action, with the tank mounted at least 12 in. above the solar absorber to avoid reverse circulation at night. In some installations it is not possible to arrange this, and under these circumstances a forced circulation system must be employed. This involves use of a circulating pump, controlled by a radiation relay or its equivalent. Tests on a system of this type installed at Highett have shown that elaboration of light-sensitive relays is unnecessary, and control of the pump's operation can be provided by a thermostat fitted in the absorber outlet header.

Solar water heaters are liable to damage by freezing in areas of heavy frost. A means of protection developed by the Section has proved satisfactory in laboratory tests, and extended field trials under winter conditions are now being carried out.

(*c*) *Temperature and Humidity Control.*—There is a requirement in most laboratories for a controlled space in which temperature, and in some cases humidity, can be maintained constant within fairly close limits. Some years ago the Section developed a room conditioner, incorporating commercial control equipment, to meet this need, and a substantial number of these units were subsequently installed at C.S.I.R.O. establishments.

A precise electronic dry- and wet-bulb temperature controller has been developed, which has made it possible to simplify this room conditioner and to reduce its size and weight. Prototypes of the new design have been tested satisfactorily and are being installed in local laboratories where performance can be observed over an extended period. These conditioners incorporate the electrode-boiler type of humidifier, which in its new single-phase form has recently been patented by the Section. In common with phytotron cabinets, their refrigeration systems use restrictor tubes in place of expansion valves for greater reliability. As data available on the design of these tubes are largely empirical, factors affecting the flow of an evaporating liquid have been examined and a test rig set up for calibrating tubes and checking their flow characteristics.

Arrangements are being completed for manufacture under licence of the electronic controller and its associated thermal transducer. The transducer is an integrating feed-back device using heat conduction principles to provide an inherently long time constant. It can be applied to a number of uses, one being stabilization of an on-off control system with the virtual elimination of overshoot. Recently the device has been reduced in size and its time constant has been made adjustable. Problems associated with its use in modulating control systems have been examined, and tests are in progress on a prototype installation.

In a rather different field, a method has been developed for measuring temperature in conveyor-type baking ovens using a telemetering system. A signal proportional to temperature is transmitted to an external receiver by a miniature radio transmitter, packed in ice in an insulated container which travels through the oven on the conveyor belt. The receiver incorporates novel filtering circuits to separate the transmitted signal from heavy extraneous interference arising from electrical ignition equipment normally associated with gas-fired ovens. Temperatures can be recorded or read directly on a meter connected to the receiver output. Patent protection has been sought for novel features of the latter, which could have other applications where noise suppression is required.

(*d*) *Agricultural Engineering Research*.—In investigating the basic principles of the mowing process, detailed knowledge is being obtained of forces acting during the cutting operation. Development is proceeding of a mower of novel type.

Application was made for patent protection for the grab-type silage loader developed by the Section. Working drawings of the machine have been made available without restrictions to various firms and individuals, and a good response has been obtained. This is indicative of the general interest being taken in the use of silage, and in equipment designed to eliminate most of the arduous labour normally associated with its removal from a pit or stack.

A programme of work has been initiated under finance supplied by the Wheat Research Trust Fund. One aspect of this work covers investigation of the kinematics of the disk plough and the forces acting on wheel and disk. Test rigs have been built to enable these forces to be measured by strain gauges in soils of different types and a vehicle has been equipped as a mobile laboratory to record readings of the gauges as the truck follows the test rig along the furrow.

A second series of investigations into wheat problems concerns moisture in grain storages. Wheat with moisture content up to a limiting value can be safely stored for long periods, but a higher moisture content causes generation of heat and deterioration of the grain. Heat and moisture transfers will take place between wet wheat and surrounding dry grain, causing progressive deterioration; the basic mechanism of these transfers will be investigated. As a first step laboratory tests are in progress to establish moisture diffusion data in packed wheat samples under forced thermal conditions. When results of these tests have been statistically evaluated, thermal and hygrometric measurements will be undertaken in larger-scale storages.

(*e*) *Processing of Scientific Data*.—From even a short test, modern instrumentation frequently produces a large amount of data for analysis. Where a test cycle ranges between one steady state and another, much tedious routine work is normally required to reduce the data to a form in which it can be handled by a Fourier analysis. An alternative approach, using digital computer processes, has been developed for recovery of linearly distorted data of this type. It provides a simplified means of processing such data, and enables time to be saved in analysis of test results.

XXXI. PUBLICATIONS, EXTENSION AND LIAISON ACTIVITIES.

1. GENERAL.

The Organization's research results are made available through various channels.

Formal scientific publication is supplemented by: preparation of films (Section 6 of this Chapter); continuous and close contact with industry by officers of Divisions and Sections; provision of facilities for guest workers in laboratories; publication of trade circulars, newsletters, and articles in trade journals; press releases; lectures and short courses of specialized training; and organization of specialist conferences.

Application of research in primary industries is being assisted by the Agricultural Research Liaison Section (Section 3 of this Chapter).

Application of research in secondary industries is being assisted by the Industrial Research Liaison Section (Section 4 of this Chapter).

Section 5 of this Chapter deals with the Organization's Scientific Liaison Offices in London and Washington.

2. PUBLICATIONS.

The Organization continued co-operation with the Australian Academy of Science to ensure maintenance of a high standard in papers appearing in the following scientific journals published by the Organization:—

Australian Journal of Agricultural Research.—Six issues a year.

Australian Journal of Applied Science.—Issued quarterly.

Australian Journal of Biological Sciences.—Issued quarterly.

Australian Journal of Botany.—Issued as material becomes available.

Australian Journal of Chemistry.—Issued quarterly.

Australian Journal of Marine and Freshwater Research.—Issued as material becomes available.

Australian Journal of Physics.—Issued quarterly.

Australian Journal of Zoology.—Issued as material becomes available.

General editorial policy is decided by a Board of Standards comprising: Professor J. G. Wood (Chairman), Dr. N. S. Noble (Editor), Professor J. S. Anderson, Professor Sir Macfarlane Burnet, Professor Sir Leslie Martin, and Professor W. P. Rogers. Advisory committees are responsible for editorial matters affecting each individual journal, and members of the Board serve on appropriate journal committees.

The Royal Australian Chemical Institute collaborates in the publication of the *Australian Journal of Chemistry;* the Institute of Physics (Australian Branch) collaborates in the publication of the *Australian Journal of Physics;* and the Australian Veterinary Association and the Australian Institute of Agricultural Science collaborate in the publication of the *Australian Journal of Agricultural Research*.

The journals listed above are open to receive contributions of merit from research workers, irrespective of country or establishment to which they are attached. Many papers have been published from workers in Australian universities and a limited number from overseas sources.

The Organization's research results are published in the above journals, in its Bulletins, in the Technical Papers of its Divisions and Sections, and in special series such as the "Land Research" series and the "Soil Publication" series. Many research papers are also contributed by officers of the Organization to specialized scientific journals both in Australia and overseas.

A complete list of scientific papers published during the year by officers of the Organization will be found in Chapter XXXIV.

3. AGRICULTURAL RESEARCH LIAISON SECTION.

This Section assists Divisions and Sections of C.S.I.R.O. by interpreting and expressing research results to aid their adoption in practice. Publications, conferences, tours, and other activities are used to improve the flow of research information to State extension officers and others. Officers of the Section are called on increasingly for advice and assistance in many phases of rural liaison work.

As in previous years, the Section's artists and photographer have assisted other groups in the preparation of publications and display material for field days, open days, and exhibits.

(*a*) *Publications.*—The year 1958-59 has been one of transition and adjustment. It has proved extremely difficult to recruit writers of the calibre needed. The Section's publications continue to attract widespread comment, and are indirectly influencing other semi-technical rural publications. Present commitments will occupy available staff for at least twelve months, and requests continue to mount for additional publications.

Four issues of *Rural Research in C.S.I.R.O.* were published during the year, and 17,500 copies distributed of each issue. Typography and layout were improved and photographs have made an increasingly important contribution. Close association of writer, artist, photographer, and printer has been a major factor in the success of *Rural Research in C.S.I.R.O.* as a channel of communication.

An important innovation during the year was the introduction of *Liaison Notes,* prepared, not for general distribution. but as a link between research and extension workers. *Liaison Notes* supplements *Rural Research in C.S.I.R.O.*. and its restricted circulation facilitates reporting on current work, and assists freer exchange of ideas between research and extension personnel. Three numbers have now been issued of a " General Series " of *Liaison Notes.* A second series, the *Sheep Series,* contains review articles on subjects dealing with sheep and wool. This is prepared at the Sheep Biology Laboratory, Prospect, and edited and distributed through the Section. Both series have been favorably received by extension officers.

(b) *Conferences.*—A symposium on rabbit control, in September, 1958, organized in co-operation with the Wildlife Survey Section, was widely attended. Known methods were discussed and evaluated for controlling this pest, and technical problems of rabbit control were reviewed.

The Section also helped to organize a conference of seed-testing officers—one of a series of technical conferences convened by C.S.I.R.O. on behalf of the Australian Agricultural Council. The conference discussed testing techniques, and Australian and international legislation governing seed testing, quarantine, and allied subjects.

In May, 1959, a group of extension officers from each State, and New Guinea, made a two-week tour of C.S.I.R.O. and other research laboratories in New South Wales, Australian Capital Territory, and Victoria. The Organization's research was seen at first hand, and information exchanged on the problem of assuring that the results of research are brought into practice.

(*c*) *Research and Advisory Activities.*—Specialist techniques are being developed in the communication of research results, and the Section has been studying the theory and principles of communication processes.

A small research programme is under way to study the most effective methods for conveying research results to the rural community. This includes analysis of extension systems in Australia and overseas, and investigation of the economic and social aspects of problems involved in applying new research results.

Another research project in which the Section is participating aims to analyse the way in which social structures and processes in a rural community affect the adoption of new methods of production; this study is being conducted in association with the University of Melbourne. Also, with the use of known research results on weather risks and food requirements of sheep during drought, an analysis is being made of the effects of maintaining drought fodder reserves at various levels.

(*d*) *Southern Tablelands Co-operative Study.*—The Section continued to co-operate in this project with Canberra Divisions and the New South Wales Department of Agriculture. The study aims to assess existing and potential agricultural resources of the Southern Tablelands, and to show how research and extension workers can co-operate to mutual advantage. Four reports were issued during the year (" Progress during 1957 ", " Water Resources ", " Climate ", and " Plant Nutrition "). Five others are being prepared.

(*e*) *Other Activities.*—During the year the Section received over 1,800 inquiries on rural problems. Many of these inquiries were answered direct, while others were referred to appropriate Divisions or State Departments of Agriculture.

The Section's Canberra office has been established as a liaison centre for C.S.I.R.O. in Canberra, and is being used increasingly for the exchange of research information.

4. INDUSTRIAL RESEARCH LIAISON SECTION.

This Section is concerned with promoting the use by Australian industry of the results of the Organization's research, fostering new contacts between industry and the Divisions and Sections, and encouraging local industry to expand its own research activities.

Research financed by the Government must chiefly be directed to basic problems affecting wide sections of industry, and it is not always possible to investigate on an effective scale some problems of particular importance to specialized branches. In many such cases, the industry concerned has provided financial support to extend the research programme of the Organization. Such sponsored research projects have become an established feature of C.S.I.R.O. activities, and the Section is concerned with making suitable arrangements for projects of this kind.

A large number of technical inquiries is handled by the Section. Wherever possible inquiries are referred to a laboratory or person experienced in the appropriate field, and the inquirer is thus able to receive direct help from those best qualified to give it. Some inquiries are received on subjects in which no work is proceeding in Australia, and in these instances information is given from published technical literature.

Six issues of *C.S.I.R.O. Industrial Research News* were produced during the year. This publication presents the results of the Organization's research in non-technical language, and places special emphasis on research developments ready for industrial application. It is circulated throughout Australian industry. Articles from *C.S.I.R.O. Industrial Research News* are widely reprinted in Australian trade journals.

In recent years the number of patents arising out of research in the Organization has been growing, and well over 300 patents and patent applications are now current, of which more than half are the subject of patent licence agreements. The Section has been increasingly involved in assisting Divisions on patenting and licensing problems and in all aspects of industrial application of the Organization's patents. In collaboration with the Divisions concerned, the Section is responsible for promotion of patents, and this function constitutes a growing proportion of the Section's activities. Each patent presents a different problem in exploitation.

5. OVERSEAS LIAISON.

The Organization has Scientific Liaison Offices in London and Washington as constituent units of the British Commonwealth Scientific Office (London), and the

British Commonwealth Scientific Office (North America). These offices maintain close contact with overseas scientific developments and serve as centres for visitors and research students from the Organization and for other visiting scientists. The Chief Scientific Liaison Officers in London and Washington have represented Australia at scientific conferences in the United Kingdom, Europe, and the United States of America. The London office has materially assisted in the recruitment of research staff from the United Kingdom and European countries.

6. Film Unit.

The following films were completed and released during the year:—

Mitosis—16 mm., colour, sound, screening time 9 min. A wholly animated film showing the normal process by which cells divide to give new cells with the same chromosome number.

The Seals of Macquarie Island—16 mm., colour, sound, screening time 13 min. Produced in collaboration with the Antarctic Division, Department of External Affairs, the film shows that fur seals have returned to Macquarie Island after being virtually wiped out by early sealers. The film also depicts the yearly cycle of life of the elephant seals which home on Macquarie Island.

Arid Zone Climatology—16 mm., colour, silent, screening time 40 min. This film is designed primarily for use by research workers of the Division of Land Research and Regional Survey in describing their work to other scientists at conferences in Australia and overseas.

Films on the following subjects are due for early release:—

Pattern for Progress—16 mm., colour, sound. This film will describe the project being undertaken with the New South Wales Department of Agriculture for survey and agricultural development of the Yass River Valley area in the Southern Tablelands of New South Wales (see Section 3 (*d*) of this Chapter).

The Challenge of the North—Part 1, *Katherine Area*—16 mm., colour, sound. In production in collaboration with the Division of Land Research and Regional Survey, this film will describe research in progress and potentialities in the Tipperary land system—an area of 8,000 square miles centred on the township of Katherine in the Northern Territory.

Also in production are films entitled—

The Biological Control of Insect Pests, Sheep Selection, and *Cattle Tick Control.*

Ninety-five prints of the Organization's films were distributed during the year, making a total of 600 prints distributed, 400 within Australia and 200 overseas, to 25 countries. Of the total distributed, 350 copies have been purchased.

Two copies of all films produced during the year were sent to the National Library, Canberra, and one copy to both the Scientific Liaison Offices in London and Washington. The National Library has purchased extra copies for exchange with overseas libraries.

Prints of the film, *The Mallee Fowl,* have been distributed through the Australian Broadcasting Commission to fifteen member countries of the European Broadcasting Union for use on television. In return, the Australian Broadcasting Commission will receive popular scientific films from member countries for use in Australia. Excerpts from the Organization's natural history films have been used in television programmes by the British Broadcasting Corporation and Associated Rediffusion, and the Canadian Broadcasting Corporation has used part of the film, *War Against the Rabbit,* in a national television programme.

Parts of the films, *Radio Astronomy in Australia,* and *Storms on the Sun,* have been used by film producers and television networks in the United States of America, in official documentary films, and in programmes associated with the International Geophysical Year.

During the year, by loans through A.S.L.O., London, and the Central Film Library, the Organization's films were screened 150 times at International Conferences and by universities, the Royal Society, the British Association for the Advancement of Science, and other leading scientific and educational bodies in the United Kingdom and elsewhere in Europe.

The following films were screened at film festivals:—

XIIth International Edinburgh Film Festival—*Radio Astronomy in Australia.*

Melbourne Film Festival—*The Seals of Macquarie Island.*

XXXII. PERSONNEL OF COUNCIL AND COMMITTEES.

1. Executive.

F. W. G. White, C.B.E., M.Sc., Ph.D. (*Deputy Chairman*).*
S. H. Bastow, D.S.O., B.Sc., Ph.D. (*Chief Executive Officer*).
A. W. Coles.
J. Melville, M.Sc., Ph.D., F.R.A.C.I.

2. Advisory Council.

Executive.
(See above.)

Chairmen of State Committees.

New South Wales—Professor H. R. Carne, D.V.Sc.
Victoria—Professor J. S. Turner, M.A., Ph.D., M.Sc., F.A.A.
Queensland—R. S. Wilson.
South Australia—Professor J. G. Wood, Ph.D., D.Sc., F.A.A.
Western Australia—Professor N. S. Bayliss, B.A., B.Sc., Ph.D., F.A.A.
Tasmania—Professor H. N. Barber, M.A., Ph.D., F.A.A.

Co-opted Members.

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L. B. Bull, C.B.E., D.V.Sc., F.A.A.
Professor H. C. Forster, M.Agr.Sc., Ph.D.
D. R. Hawkes.
A. McCulloch, M.E.
M. A. Mawby, D.Sc., F.S.T.C.
B. Meecham, O.B.E.
W. W. Pettingell, O.B.E., B.Sc.
E. P. S. Roberts.
Professor J. W. Roderick, M.A., Ph.D., M.Sc., F.A.A.
W. J. Russell, A.C.I.A.
E. M. Schroder.
W. Sloan.
H. B. Somerset, M.Sc.
J. V. Vernon, B.Sc., Ph.D.
L. W. Weickhardt, M.Sc.
C. M. Williams, O.B.E.

3. State Committees.

New South Wales.

Professor H. R. Carne, D.V.Sc. (*Chairman*).
Professor A. E. Alexander, B.Sc., M.A., Ph.D., Sc.D.
Professor J. P. Baxter, C.M.G., O.B.E., B.Sc., Ph.D., F.A.A.
F. S. Bradhurst, D.Sc.
J. N. Briton, B.Sc., B.E.
S. F. Cochran, F.A.S.A.

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* Dr. F. W. G. White was appointed Chairman of the Organization as from 1st July, 1959.

Professor R. L. Crocker, D.Sc.
The Hon. O. McL. Falkiner, M.L.C.
W. R. Hebblewhite, B.E.
E. L. S. Hudson, Dip.For.
The Hon. Sir Norman Kater, M.L.C., M.B., Ch.M.
J. F. Litchfield.
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Emeritus Professor Sir John Madsen, B.E., D.Sc., F.A.A.
C. St. J. Mulholland, B.Sc.
Professor D. M. Myers, B.Sc., D.Sc.Eng.
R. J. Noble, C.B.E., B.Sc.Agr., M.Sc., Ph.D.
R. G. O. Parry-Okeden.
A. R. Penfold, A.S.T.C., F.R.A.C.I.
W. W. Pettingell, O.B.E., B.Sc.
Professor D. W. Phillips, B.Sc., Ph.D.
L. A. Pockley, B.V.Sc.
Associate Professor F. H. Reuter, Ph.D.
Professor J. W. Roderick, M.A., M.Sc., Ph.D., F.A.A.
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W. Sloan.
J. Vernon, B.Sc., Ph.D.
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Emeritus Professor R. D. Watt, M.A., B.Sc.Agric.
Professor W. H. Wittrick, M.A., Ph.D., F.A.A.
A. J. Higgs, B.Sc. (*Secretary*).

Victoria.

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D. T. Boyd, C.M.G.
L. B. Bull, C.B.E., D.V.Sc., F.A.A.
Sir Macfarlane Burnet, O.M., M.D., Ph.D., D.Sc., F.A.A., F.R.S., F.R.C.P.
W. H. Connolly, B.E.E., B.Com.
S. B. Dickinson, M.Sc.
Professor H. C. Forster, M.Agr.Sc., Ph.D.
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Emeritus Professor Sir Samuel Wadham, M.A., LL.D., Dip.Agr.
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L. W. Weickhardt, M.Sc.
F. G. Nicholls, M.Sc. (*Secretary*).

Queensland.

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L. H. McDonald.
J. F. Meynink.
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O. E. J. Murphy, M.B., Ch.M.
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R. M. Reynolds.
E. P. S. Roberts.
Professor M. Shaw, M.E., M.Mech.E.
W. J. D. Shaw.
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Professor L. J. H. Teakle, B.Sc.Agr., M.S., Ph.D.
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C. Haselgrove.
J. C. Hawker, B.A.
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Tasmania.

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P. R. Stone.
D. Martin, D.Sc. (*Secretary*).

4. COMMONWEALTH RESEARCH STATION, MERBEIN—CONSULTATIVE COMMITTEE.

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L. W. Andrew, Growers' Representative, South Australian River Council of A.D.F.A.
G. Black, Growers' Representative, Robinvale.
E. T. Bowen, Renmark Irrigation Trust.
F. T. Bowman, Ph.D., M.Sc.Agr., H.D.A., Department of Agriculture, New South Wales.
J. Brown, Swan Hill Irrigators' Research Committee.
A. E. Cameron, Mildura District Citrus Growers' Association.
J. Clift, Irymple Packing Company.
D. W. Cockroft, Growers' Representative, Woorinen.
C. E. Cole, B.Agr.Sc., Department of Agriculture, Victoria.
R. Drummond, B.C.E., State Rivers and Water Supply Commission, Victoria.
W. P. Dunk, M.Agr.Sc., State Rivers and Water Supply Commission, Victoria.
W. V. Ford, Mildura Co-operative Fruit Company.
W. B. Hawson, Growers' Representative, First Mildura Irrigation Trust.
A. E. Hazel, Growers' Representative, Red Cliffs.
S. Heaysman, Growers' Representative, Coomealla.
T. Hill, Growers' Representative, Curlwaa.
G. Hobson, Growers' Representative, Nyah West.
H. Jackson, Wakool Land Use Committee.
J. H. Lapthorne, Growers' Representative, Merbein.
T. C. Miller, B.Agr.Sc., Department of Agriculture, South Australia.
W. I. Nankovell, B.Agr.Sc., Department of Agriculture, Victoria.
F. S. Oldham, Department of Agriculture, New South Wales.
F. Penman, M.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein.
R. C. Polkinghorne, Growers' representative, Woorinen.
A. Seekamp, Growers' representative, Loxton Agricultural Bureau.
J. V. Seekamp, B.Agr.Sc., Growers' representative, South Australian River Council of A.D.F.A.

5. IRRIGATION RESEARCH AND EXTENSION COMMITTEE (MURRUMBIDGEE IRRIGATION AREAS).

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A. E. Bowmaker, Ricegrowers' Association of Australia, Leeton.
S. J. Bowyer, Rural Bank of New South Wales, Sydney.
H. V. Chaseling, Ricegrowers' Association of Australia, Griffith.
G. M. Clark, Yenda Producers' Co-operative Society, Yenda.
E. S. Clayton, H.D.A., Soil Conservation Service of New South Wales, Sydney.
H. Cooke, Private Industry, Griffith.
G. A. Crawford, H.D.A., New South Wales Department of Agriculture, Leeton.
J. L. H. Davies, Murrumbidgee Irrigation Dairy Farmers.
H. N. England, B.Sc., Water Conservation and Irrigation Commission of New South Wales, Sydney.
M. N. Errey, Leeton Fruitgrowers' Co-operative Society, Leeton.
E. R. Hoare, B.Sc., M.I.E.E., Irrigation Research Station, C.S.I.R.O., Griffith.
W. N. Hogan, M.I.A. District Council of Extension Groups, Griffith.
C. R. Hood, H.D.A., New South Wales Department of Agriculture, Leeton.
H. J. Hynes, D.Sc.Agr., M.Sc., New South Wales Department of Agriculture, Sydney.
A. Jenkins, Leeton District Citrus Growers' Association.
B. G. Lowe, Leeton Co-operative Cannery, Leeton.
R. J. McCleary, M.I.A. Vegetable Growers' Association, Leeton.
A. D. Mackellar, Ricegrowers' Co-operative Mills, Leeton.
F. J. McKirdy, Rural Bank of New South Wales, Leeton.
J. R. A. McMillan, D.Sc.Agr., M. S., University of Sydney.
L. F. Myers, M.Agr.Sc., Regional Pastoral Laboratory, C.S.I.R.O., Deniliquin.
F. Penman, M.Sc., Irrigation Research Stations, C.S.I.R.O., Merbein and Griffith.
J. Ramsbottom, Water Conservation and Irrigation Commission, Leeton.
H. W. Raphael, M.I.A. District Council of Extension Groups, Griffith.
R. Sainty, M.I.A. District Council of Extension Groups, Griffith.
C. E. Sharam, Ricegrowers' Association of Australia, Griffith.
A. H. Skepper, H.D.A., New South Wales Department of Agriculture, Leeton.
W. F. Townsend, Producers' Co-operative Distributing Society, Leeton.
A. J. Grassby (*Secretary-Treasurer*).

6. REGIONAL PASTORAL LABORATORY, ARMIDALE—TECHNICAL LIAISON COMMITTEE.

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G. Edgar, B.V.Sc., Department of Agriculture, New South Wales.
O. H. Frankel, D.Sc., D.Agr., F.A.A., F.R.S., Division of Plant Industry, C.S.I.R.O.
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M. A. McDonald, H.D.A., Department of Agriculture, New South Wales.
R. B. Madgwick, M.Ec., D.Phil., University of New England.
Professor A. F. O'Farrell, B.Sc., A.R.C.S., F.R.E.S., University of New England.
R. Roe, B.Sc.(Agric.), Division of Plant Industry, C.S.I.R.O.
C. J. Vears, B.Sc.Agr., Department of Agriculture, New South Wales.
M. H. Walker, B.Sc.,Agr., Department of Agriculture, New South Wales.
J. F. Barrett, B.V.Sc., Division of Animal Health and Production, C.S.I.R.O. (*Secretary*).

7. REGIONAL PASTORAL LABORATORY, ARMIDALE—CONSULTATIVE COMMITTEE.

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J. Bowers, Australian Primary Producers' Union.
A. G. Brett, Graziers' Association of New South Wales.
A. W. Cameron, Graziers' Association of New South Wales.
A. T. Dick, D.Sc., Division of Animal Health and Production, C.S.I.R.O.
L. P. Dutton, Council of Advice to the Pastures Protection Board, New South Wales.
E. R. Elliott, Australian Primary Producers' Union.
J. Ferris, Australian Primary Producers' Union.
G. E. Forster, Graziers' Association of New South Wales.
O. H. Frankel, D.Sc., D.Agr., F.A.A., F.R.S., Division of Plant Industry, C.S.I.R.O.
W. J. Gall, Graziers' Association of New South Wales.

I. L. Johnstone, B.V.Sc., Coopted member.
D. P. Macansh, Graziers' Association of New South Wales.
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R. B. Madgwick, M.Ec., D.Phil., University of New England.
A. S. Nivison, Graziers' Association of New South Wales.
Professor A. F. O'Farrell, B.Sc., A.R.C.S., F.R.E.S., University of New England.
R. Roe, B.Sc.(Agric.), Division of Plant Industry, C.S.I.R.O.
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E. J. Waring, B.Sc.Agr., University of New England.
A. Weir, Australian Primary Producers' Union.
A. W. Weller, Australian Primary Producers' Union.
H. F. White, Graziers' Association of New South Wales.
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Miss H. N. Turner, B.Arch., Division of Animal Health and Production, C.S.I.R.O.
A. L. Clay, B.V.Sc., Department of Agriculture and Stock, Queensland.
C. H. S. Dolling, B.Ag.Sc., Division of Animal Health and Production, C.S.I.R.O. (*Secretary*).

10. Advisory Committee on Fruit Cool Storage Investigations in New South Wales.

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F. T. Bowman, B.Sc., Agr., M.Sc., Ph.D., Department of Agriculture, New South Wales.
Professor R. L. Crocker, M.Sc., Ph.D., University of Sydney.
J. K. Long, B.Sc.Agr., Department of Agriculture, New South Wales.
R. N. Robertson, B.Sc., Ph.D., F.A.A., Division of Food Preservation and Transport, C.S.I.R.O.
R. B. Withers, M.Sc., Dip.Ed., Division of Food Preservation and Transport, C.S.I.R.O. (*Secretary*).

11. Committee for Co-ordination of Fruit and Vegetable Storage Research.

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J. K. Long, B.Sc.Agr., Department of Agriculture, New South Wales.
D. Martin, D.Sc., Division of Plant Industry, C.S.I.R.O.
F. Melville, B.Sc., Department of Agriculture, Western Australia.
T. C. Miller, B.Sc.(Agric.), Department of Agriculture, South Australia.
T. D. Raphael, M.A., Dip.Hort. (Cantab.), Department of Agriculture, Tasmania.
R. N. Robertson, B.Sc., Ph.D., F.A.A., Division of Food Preservation and Transport, C.S.I.R.O.
S. A. Trout, M.Sc., Ph.D., Department of Agriculture and Stock, Queensland.
R. B. Withers, M.Sc., Dip.Ed., Division of Food Preservation and Transport, C.S.I.R.O. (*Secretary*).

12. Committee for Co-ordination of Research on Fruit and Vegetable Processing.

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J. A. Holbeche, H.D.A., Department of Agriculture, New South Wales.
J. F. Kefford, M.Sc., Division of Food Preservation and Transport, C.S.I.R.O.
L. J. Lynch, B.Agr.Sc., Division of Food Preservation and Transport, C.S.I.R.O.
D. McG. McBean, B.Sc., Division of Food Preservation and Transport, C.S.I.R.O.
H. R. Richardson, B.Sc.Agr., Department of Agriculture, New South Wales.
N. S. Shirlow, B.Sc.Agr., Department of Agriculture, New South Wales.
P. W. Board, B.Sc.(Hons.), Division of Food Preservation and Transport, C.S.I.R.O. (*Acting Secretary*).

13. Dried Fruits Processing Committee.

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W. R. Jewell, M.Sc., B.Met., Department of Agriculture, Victoria.
F. J. Lesock, B.Agr.Sc., Department of Primary Industry, Melbourne.
T. C. Miller, B.Sc.(Agric.), Department of Agriculture, South Australia.
W. I. Nankivell, B.Agr.Sc., Department of Agriculture, Victoria.
H. R. Tinney, B.V.Sc., Department of Primary Industry.
J. R. Vickery, M.Sc., Ph.D., Division of Food Preservation and Transport, C.S.I.R.O.

14. Advisory Committee on Fruit Storage Investigations in Victoria.

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S. Fish, M.Agr.Sc., Department of Agriculture, Victoria.
R. N. Robertson, B.Sc., Ph.D., F.A.A., Division of Food Preservation and Transport, C.S.I.R.O.
J. R. Vickery, M.Sc., Ph.D., Division of Food Preservation and Transport, C.S.I.R.O.

15. Melbourne Ore-Dressing Sub-Committee.

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W. Baragwanath, O.B.E., A.S.M.B., Melbourne.
Associate Professor H. H. Dunkin, B.Met.E., University of Melbourne.
R. B. Mills, B.Sc., Electrolytic Zinc Co. Ltd., Melbourne.
G. B. O'Malley, B.Met.E., Melbourne.
K. S. Blaskett, B.E., Ore-dressing Investigations, C.S.I.R.O. (*Secretary*).

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R. A. Hobson, B.Sc.(Hons.), School of Mines, Kalgoorlie, Western Australia.
C. Yates, B.E., Australasian Institute of Mining and Metallurgy.

17. MINERAGRAPHIC COMMITTEE.

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W. E. Wainwright, A.S.A.S.M., Australasian Institute of Mining and Metallurgy.

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F. J. Lehany, M.Sc., Division of Electrotechnology, C.S.I.R.O.
Professor D. M. Myers, B.Sc., D.Sc.Eng., University of Sydney.
F. W. G. White, C.B.E., M.Sc., Ph.D., C.S.I.R.O.
F. G. Nicholls, M.Sc., C.S.I.R.O. (*Conjoint Secretary*).
R. C. Richardson, B.E., Division of Electrotechnology, C.S.I.R.O. (*Conjoint Secretary*).

19. RADIO RESEARCH BOARD.

Professor L. G. H. Huxley, M.A., D.Phil., Ph.D., F.A.A., University of Adelaide (*Chairman*).
J. L. Farrands, B.Sc., Ph.D., D.I.C., Department of the Army.
T. Housley, B.Sc., Overseas Telecommunications Commission.
N. J. McCay, B.Sc., P.M.G. Research Laboratories.
D. McDonald, B.Sc., Australian Broadcasting Control Board.
Cmdr. J. R. McMurray, R.A.N., Department of the Navy.
Group-Captain J. W. Reddrop, O.B.E., R.A.A.F., Department of Air.
E. Sawkins, B.Sc., Postmaster-General's Department.
Professor H. C. Webster, D.Sc., Ph.D., University of Queensland.
F. W. G. White, C.B.E., M.Sc., Ph.D., C.S.I.R.O.
W. F. Evans, B.Sc., C.S.I.R.O. (*Secretary*).

20. CONSULTATIVE COMMITTEE ON RADIO RESEARCH.

F. W. G. White, C.B.E., M.Sc., Ph.D., C.S.I.R.O. (*Chairman*).
E. W. Anderson, A.M.I.E.(Aust.), Department of Civil Aviation.
W. G. Baker, D.Sc.(Eng.), Ionospheric Prediction Service.
E. G. Bowen, O.B.E., M.Sc., Ph.D., F.A.A., Division of Radiophysics, C.S.I.R.O.
J. D. Campbell, Telecommunications Advisory Committee.
B. G. Gates, B.Sc., Ph.D., D.I.C., Department of Supply.
Lieut.-Col. G. J. Gay, Department of the Army.
Cmdr. R. D. Green, R.A.N., Department of the Navy.
R. R. Long, B.E.E., Overseas Telecommunications Commission (Aust.).
N. J. McCay, B.Sc., Postmaster-General's Department.
A. J. McKenzie, M.E.E., Australian Broadcasting Control Board.
Emeritus Professor Sir John Madsen, B.E., D.Sc., F.A.A.
D. F. Martyn, D.Sc., Ph.D., A.R.C.S., F.A.A., F.R.S., Upper Atmosphere Section, C.S.I.R.O.
G. H. Munro, D.Sc., C.S.I.R.O.
J. L. Pawsey, M.Sc., Ph.D., F.A.A., F.R.S., Division of Radiophysics, C.S.I.R.O.
L. S. Prior, B.Sc., Bureau of Mineral Resources, Geology and Geophysics.
Group Captain J. W. Reddrop, O.B.E., R.A.A.F., Department of Air.
E. J. Stewart, B.Sc., Postmaster-General's Department.
W. F. Evans, B.Sc., C.S.I.R.O. (*Secretary*).

21. BUILDING RESEARCH COMMITTEE.

I. Langlands, M.Mech.E., B.E.E., Division of Building Research, C.S.I.R.O. (*Chairman*).
G. D. Aitchison, Ph.D., M.E., Soil Mechanics Section, C.S.I.R.O.
R. E. Banks, B.Sc.(Eng.), Building Research Liaison Service, Melbourne.
S. H. Bastow, D.S.O., B.Sc., Ph.D., C.S.I.R.O.
A. L. Brentwood, B.C.E., B.E.E., Department of Labour and National Service.
S. A. Clarke, B.E., Division of Forest Products, C.S.I.R.O.
J. W. Drysdale, B.E., Commonwealth Experimental Building Station, Sydney.
Professor A. J. Francis, M.Sc., Ph.D., M.C.E., University of Melbourne.
D. V. Isaacs, M.C.E., Commonwealth Experimental Building Station, Sydney.
J. R. Barned, B.Sc., Division of Building Research, C.S.I.R.O. (*Secretary*).

22. PATENTS COMMITTEE.

I. Langlands, M.Mech.E., B.E.E., Division of Building Research, C.S.I.R.O. (*Chairman*).
F. J. Lehany, M.Sc., Division of Electrotechnology, C.S.I.R.O.
L. Lewis, B.Met.E., Industrial Research Liaison Section, C.S.I.R.O.
M. Lipson, B.Sc., Ph.D., Division of Textile Industry, Geelong, C.S.I.R.O.
F. G. Nicholls, M.Sc., C.S.I.R.O.
K. L. Sutherland, D.Sc., Ph.D., Division of Physical Chemistry, C.S.I.R.O.
J. P. Shelton, M.Sc., A.B.S.M., C.S.I.R.O. (*Secretary*).

23. C.S.I.R.O. STUDENTSHIP ADVISORY COMMITTEE.

S. H. Bastow, D.S.O., B.Sc., Ph.D., C.S.I.R.O. (*Chairman*).
Professor R. L. Crocker, D.Sc., University of Sydney.
D. T. C. Gillespie, M.Sc., C.S.I.R.O.
G. B. Gresford, B.Sc., A.R.M.T.C., C.S.I.R.O.
Professor L. G. H. Huxley, M.A., D.Phil., F.A.A., University of Adelaide.
Professor E. J. Underwood, B.Sc.(Agr.), Ph.D., F.A.A., University of Western Australia.
I. W. Wark, D.Sc., Ph.D., F.A.A., C.S.I.R.O.
W. M. Balding, B.Sc., C.S.I.R.O. (*Secretary*).

24. FOUNDRY SANDS COMMITTEE.

A. F. Dunbar, B.Sc., F.I.M., M.Aus.I.M.M., Royal Melbourne Technical College (*Chairman*).
W. E. Ewers, M.Sc., Division of Industrial Chemistry, C.S.I.R.O.

25. FODDER CONSERVATION ADVISORY COMMITTEE.

Professor H. C. Forster, M.Agr.Sc., Ph.D., University of Melbourne (*Chairman*).
F. J. R. Hird, M.Agr.Sc., Ph.D., University of Melbourne.
W. L. Greenhill, M.E., Fodder Conservation Section, C.S.I.R.O.
G. W. Lanigan, M.Sc., Fodder Conservation Section, C.S.I.R.O.

26. FIBROUS PLASTER RESEARCH LIAISON COMMITTEE.

I. Langlands, M.Mech.E., B.E.E., Division of Building Research, C.S.I.R.O. (*Chairman*).
G. K. Condon, Associated Fibrous Plaster Manufacturers of Australia.
J. Fanning, Associated Fibrous Plaster Manufacturers of Australia.

K. Hopkins, Associated Fibrous Plaster Manufacturers of Australia.

A. C. Mitchinson, Associated Fibrous Plaster Manufacturers of Australia.

M. J. Ridge, M.Sc., Division of Building Research, C.S.I.R.O.

E. A. Willis, M.L.A., Associated Fibrous Plaster Manufacturers of Australia.

J. R. Barned, B.Sc., Division of Building Research, C.S.I.R.O. (*Secretary*).

27. PAINT ON PLASTER RESEARCH COMMITTEE.

I. Langlands, M.Mech.E., B.E.E., Division of Building Research, C.S.I.R.O. (*Chairman*).

E. V. Collins, Australian Paint Manufacturers' Federation.

L. Durie, Australian Paint Manufacturers' Federation.

S. R. Heron, Australian Paint Manufacturers' Federation.

J. H. Hesketh, F.R.A.C.I., Australian Paint Manufacturers' Federation.

E. Hoffmann, Dr.Phil., Division of Building Research, C.S.I.R.O.

C. Moore, Ph.D., Australian Paint Manufacturers, Federation.

E. P. Sanford, Australian Paint Manufacturers' Federation.

G. C. Wallis, Australian Paint Manufacturers' Federation.

E. B. Young, Australian Paint Manufacturers' Federation.

J. R. Barned, B.Sc., Division of Building Research, C.S.I.R.O. (*Secretary*).

XXXIII. STAFF.

The following is a list of the professional staff of the Organization as at 30th June, 1959:—

1. HEAD OFFICE.

(Head-quarters: 314 Albert-street, East Melbourne.)

Deputy Chairman—F. W. G. White,[*] C.B.E., M.Sc., Ph.D.

Chief Executive Officer—S. H. Bastow, D.S.O., B.Sc., Ph.D.

Research Secretary (Scientific Services)—F. G. Nicholls, M.Sc.

Research Secretary (Physical Sciences)—G. B. Gresford, B.Sc., A.R.M.T.C.

Research Secretary (Biological Sciences)—W. Ives, M.Ec.

Secretary (Finance and Supplies)—M. G. Grace, A.A.S.A.

Assistant Research Secretary (Physical Sciences)—D. T. C. Gillespie, M.Sc.

Assistant Research Secretary (Biological Sciences)—P. F. Butler, M.Ag.Sc.

Senior Research Officer—W. F. Evans, B.Sc.

Senior Research Officer—W. M. Balding, B.Sc.

Experimental Officer—A. K. Klingender, B.Sc.

Experimental Officer—L. G. Wilson, M.Sc.

Library—

Chief Librarian—Miss B. C. L. Doubleday, M.A.

Scientific Librarian—Miss M. L. Cameron, B.Sc.

Scientific Librarian—Miss J. A. Conochie, B.Sc.

Scientific Librarian—Miss L. J. Davey, B.Sc.

Scientific Librarian—Miss J. C. Kahan, B.Sc. (at Perth).

Scientific Librarian—Miss H. M. Storie, B.Sc., F.R.M.T.C.

Librarian—Mrs. P. Cronshaw, A.L.A.

Librarian—Miss P. D. Prendergast, B.A.

Union Catalogue of Periodicals, Editor—Miss A. L. Kent.

Experimental Officer—Miss J. Dunstone, B.Sc., Dip.Ed.

Accounts—

Accountant—D. J. Bryant, A.A.S.A.

Finance—

Assistant Secretary (Finance and Supplies)—R. W. Viney, A.A.S.A., A.C.I.S.

Stock Records—

J. M. Short, A.A.S.A., A.C.I.S.

Orders and Transport—

V. H. Leonard, J.P.

Staff—

Staff Relations Officer—L. G. Peres, B.Ec.

Senior Staff Officer—J. Coombe.

Records—

P. Knuckey.

Publishing Section—

T. R. Hunter.

Liaison Overseas—

London—

Chief Scientific Liaison Officer—E. J. Drake, F.R.A.C.I.

Senior Research Officer—R. C. Richardson, B.E.

Washington—

Chief Scientific Liaison Officer—T. B. Paltridge, B.Sc.(Hons.).

Translation Section—

Translator-in-charge—A. L. Gunn.

Translator—E. Feigl, Ph.D.

Translator—Mrs. M. Slade.

Translator—Miss M. J. Hardy, B.A.(Hons.).

Translator—C. Wouters, Ph.D.(Lit.) (at Sydney).

Translator—P. A. Kazakov, LL.B. (at Sydney).

Translator—R. J. Zatorski, B.A.(Hons.).

Film Unit—

Senior Research Officer—S. T. Evans, B.Sc.

Architectural—

Architect—W. R. Ferguson, B.E.

2. SECRETARIES OF STATE COMMITTEES.

New South Wales—

A. J. Higgs, B.Sc.(Hons.), Division of Radiophysics, University of Sydney.

Victoria—

F. G. Nicholls, M.Sc., 314 Albert-street, East Melbourne.

Queensland—

W. W. Bryan, M.Sc.Agr., Cunningham Laboratory, Mill-road, St. Lucia, S.W.6, Queensland.

South Australia—

A. W. Peirce, D.Sc., Division of Biochemistry and General Nutrition, University of Adelaide.

Western Australia—

R. P. Roberts, M.Sc.(Agric.), Department of Agriculture, Perth.

Tasmania—

D. Martin, D.Sc., " Stowell ", Stowell-avenue, Hobart.

3. AGRICULTURAL RESEARCH LIAISON SECTION.

(Head-quarters: 314 Albert-street, East Melbourne.)

At Head-quarters, East Melbourne—

Officer-in-charge—D. B. Williams, B.Sc.Agr., B.Com., Ph.D.

Principal Research Officer—K. Loftus Hills, M.Agr.Sc.

Senior Research Officer—Mrs. J. Tully, B.Sc.(Hons.), Ph.D.

Research Officer—J. L. Dillon, B.Sc.Agr., Ph.D.

Research Officer—J. J. Lenaghan, B.Agr.Sc., M.S.

Research Officer—G. F. Smith, M.A.(Cantab.).

Experimental Officer—R. N. Farquhar, B.Agr.Sc.

Experimental Officer—N. L. Tyshing, B.Sc.Agr.

Divisional Administrative Officer—A. G. K. Crass, M.A.

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[*] Dr. F. W. G. White was appointed Chairman of the Organization as from 1st July, 1959.

At Canberra—

Principal Research Officer—D. V. Walters, M.Agr.Sc.
Experimental Officer—K. D. Woodyer, B.Sc.Agr.

4. Animal Genetics Section.

(Head-quarters: University of Sydney.)

Officer-in-charge—J. M. Rendel, B.Sc., Ph.D.
Principal Research Officer—A. S. Fraser, M.S., Ph.D.
Senior Research Officer—G. W. Grigg, M.Sc., Ph.D.
Senior Research Officer—H. Hoffman, B.Sc., M.Sc., Ph.D.
Senior Research Officer—W. R. Sobey, B.Sc., Ph.D.
Research Officer—T. Nay.
Research Officer—B. L. Sheldon, B.Agric.Sc.(Hons.).
Experimental Officer—M. J. Burford, B.Sc.
Experimental Officer—Miss B. M. Kindred, B.Sc.(Hons.).
Experimental Officer—D. H. Sergeant, B.Agric.Sc.
Experimental Officer—K. E. Turnbull, B.A.

5. Division of Animal Health and Production.

(Head-quarters: Cnr. Flemington-road and Park-street, Parkville, Melbourne.)

At Divisional Head-quarters, Melbourne—

Chief—D. A. Gill, M.R.C.V.S., D.V.S.M.
Divisional Secretary—A. J. Vasey, B.Agr.Sc.
Assistant Divisional Secretary—A. B. Hackwell, B.Agr.Sc.

At Animal Health Research Laboratory, Melbourne—

Assistant Chief of Division and Officer-in-charge—T. S. Gregory, D.V.Sc., Dip.Bact.
Assistant Chief of Division—A. W. Turner, O.B.E., D.Sc., D.V.Sc., F.A.A.
Senior Research Fellow—L. B. Bull, C.B.E., D.V.Sc., F.A.A.
Senior Principal Research Officer—A. T. Dick, D.Sc.
Principal Research Officer—E. L. French, M.Sc., Ph.D.
Principal Research Officer—A. W. Rodwell, M.Sc., Ph.D.
Principal Research Officer—R. H. Watson, D.Sc.Agr.
Senior Research Officer—A. T. Dann, M.Sc.
Senior Research Officer—I. D. B. Newsam, Ph.D., M.R.C.V.S.
Senior Research Officer—J. E. Peterson, B.V.Sc.
Research Officer—G. S. Cottew, B.Sc.
Research Officer—J. F. Eadie, B.Sc.(Hons.).
Research Officer—Miss V. E. Hodgetts, B.Sc.
Research Officer—P. Plackett, B.A., Ph.D.
Research Officer—H. M. Radford, B.Sc.
Senior Experimental Officer—J. B. Bingley, D.A.C.
Experimental Officer—S. H. Buttery, B.Sc.
Experimental Officer—Miss C. E. Eales, B.Sc.
Experimental Officer—D. D. Leaver, B.V.Sc.
Experimental Officer—Miss M. J. Monsbourgh, B.Sc.
Experimental Officer—W. A. Snowdon, B.V.Sc.
Scientific Librarian—Miss F. V. Murray, M.Sc.
Divisional Administrative Officer—J. M. McMahon, B.Com.

At Poultry Research Centre, Werribee, Victoria—

Officer-in-charge—F. Skaller, M.Agr.Sc., B.Com.
Senior Research Officer—J. A. Morris, B.Sc.Agr. (Hons.), Ph.D.
Senior Research Officer—F. E. Binet, M.D.
Experimental Officer—Miss L. W. Bobr, M.Sc.(Agr.) (on study leave).

At McMaster Animal Health Laboratory, Sydney—

Officer-in-charge—D. F. Stewart, D.V.Sc., Dip.Bact.
William McIlrath Fellow in Animal Husbandry—M. C. Franklin, M.Sc., Ph.D.
Senior Principal Research Officer—H. McL. Gordon, B.V.Sc.
Senior Principal Research Officer—Miss H. Newton Turner, B.Arch.
Senior Research Officer—N. P. H. Graham, B.V.Sc.
Senior Research Officer—A. A. Dunlop, M.Agr.Sc., Ph.D.
Senior Research Officer—C. H. Gallagher, B.V.Sc., Ph.D.
Senior Research Officer—Miss J. H. Koch, M.D.
Senior Research Officer—M. D. Murray, B.Sc. (Vet.Sci.), F.R.C.V.S.
Senior Research Officer—R. I. Somerville, M.Sc.Agr. (Hons.).
Research Officer—P. K. Briggs, B.Sc.Agr.(Hons.) (on study leave).
Research Officer—I. G. Pearson, B.V.Sc.
Research Officer—L. E. A. Symons, B.V.Sc. (Hons.).
Research Officer—Mrs. N. Carter, B.Sc.
Research Officer—J. H. Thomas, B.V.Sc. (on study leave).
Research Officer—D. S. Roberts, B.V.Sc.
Research Officer—B. A. Panaretto, B.V.Sc. (on study leave).
Research Officer—G. M. Tallis, M.Sc., Ph.D.
Research Officer—S. S. Y. Young, B.Agr.Sc.
Senior Experimental Officer—A. Packham, B.V.Sc., A.A.S.A.
Experimental Officer—J. C. Boray, D.V.M.
Experimental Officer—K. J. Farrington, B.Sc., A.S.T.C.
Experimental Officer—T. J. Grainger, B.Sc.
Scientific Librarian—Miss A. G. Culey, M.Sc.

At Sheep Biology Laboratory, Prospect, New South Wales—

Assistant Chief of Division and Officer-in-charge—I. W. McDonald, B.V.Sc., B.Sc., Ph.D.
Technical Secretary—J. H. Elliott, B.Sc.(Hons.).
Senior Principal Research Officer—J. C. D. Hutchinson, M.A.
Principal Research Officer—K. A. Ferguson, B.V.Sc., Ph.D.
Principal Research Officer—G. R. Moule, D.V.Sc.
Principal Research Officer—R. L. Reid, B.Sc.Agr. (Hons.), Ph.D.
Principal Research Officer—P. G. Schinckel, B.V.Sc.
Senior Research Officer—G. Alexander, M.Agr.Sc.
Senior Research Officer—A. W. H. Braden, B.Sc., Ph.D.
Senior Research Officer—A. M. Downes, M.Sc.
Senior Research Officer—A. G. Lyne, B.Sc., Ph.D.
Senior Research Officer—B. F. Short, M.Agr.Sc., Ph.D.
Research Officer—A. H. Brook, B.V.Sc.
Research Officer—N. McC. Graham, B.Sc.(Hons.), B.Agr.(Hons.), Ph.D.
Research Officer—J. P. Hogan, B.Sc.Agr.(Hons.), Ph.D.
Research Officer—H. R. Lindner, B.V.Sc. (on study leave).
Research Officer—P. J. Reis, B.Sc.Agr.(Hons.) (on study leave).
Research Officer—B. D. Stacy, B.Sc.(Hons.), Ph.D.
Research Officer—G. M. H. Waites, B.Sc., M.A., Ph.D.
Research Officer—A. L. C. Wallace, B.Sc.
Research Officer—A. C. I. Warner, B.Sc., Dip.Microbiol., Ph.D.
Research Officer—R. H. Weston, B.Sc.Agr.(Hons.) (on study leave).
Research Officer—Manika M. Wodzicka, M.Agr.Sc., Ph.D.
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Experimental Officer—R. E. Chapman, B.Sc.App. (Hons.).
Experimental Officer—J. W. Bennett, B.Sc.
Experimental Officer—Mrs. J. Date, B.Sc.Agr.
Experimental Officer—Miss M. J. Heideman, B.A.

Experimental Officer—N. T. Hinks, B.Sc., A.S.T.C.
Experimental Officer—R. L. Hughes, B.Sc.
Experimental Officer—C. S. Mills, B.Sc., A.S.T.C.
Experimental Officer—Mrs. M. J. Rigby, B.Sc.
Experimental Officer—L. F. Sharry, A.M.T.C.
Experimental Officer—A. D. Stewart, B.Sc.
Experimental Officer—A. R. Till, B.Sc.
Experimental Officer—Miss P. A. Turner, B.Sc.
Experimental Officer—J. K. Voglmayr, B.Agr.Sc.
Experimental Officer—D. Williams, B.Agr.Sc.
Scientific Librarian—G. G. Allen, M.A.

At Regional Pastoral Laboratory, Armidale, New South Wales—
Executive Officer to Research Committee—J. F. Barrett, B.V.Sc.
Senior Research Officer—W. H. Southcott, B.V.Sc.
Senior Research Officer—L. J. Lambourne, M.Sc.
Experimental Officer—J. M. George, B.Sc.Agr.
Experimental Officer—D. B. Muirhead, R.D.A.

At McMaster Field Station, Badgery's Creek, New South Wales—
Officer-in-charge—R. H. Hayman, M.Agr.Sc.
Senior Research Officer—D. F. Dowling, B.V.Sc., B.Sc., Ph.D.
Research Officer—T. E. Allen, B.Sc.
Experimental Officer—Y. S. Pan, M.Sc., B.Sc.Agr.

At Veterinary Parasitology Laboratory, Yeerongpilly, Queensland—
Officer-in-charge—F. H. S. Roberts, D.Sc.
Principal Research Officer—R. F. Riek, B.V.Sc., M.Sc.
Senior Research Officer—P. H. Durie, M.Sc.
Research Officer—K. C. Bremner, M.Sc.
Research Officer—P. Elek, LL.D., B.V.Sc.
Research Officer—D. F. Mahoney, B.V.Sc.
Experimental Officer—K. E. Dixon, B.Sc.
Experimental Officer—R. K. Keith, A.R.A.C.I., Dip.Ind.Chem.

At National Cattle Breeding Station, "Belmont", Rockhampton, Queensland—
Officer-in-charge—J. F. Kennedy, M.Agr.Sc.
Principal Research Officer—H. G. Turner, B.Agr.Sc., M.A.
Senior Research Officer—G. C. Ashton, B.Sc.
Experimental Officer—R. W. Hewetson,B.V.Sc.
Experimental Officer—G. T. French, B.V.Sc.
Experimental Officer—A. V. Schleger, B.Sc.

At National Field Station, "Gilruth Plains", Cunnamulla, Queensland—
Officer-in-charge—C. H. S. Dolling, M.Agr.Sc.
Experimental Officer—R. W. Moore, B.Agr.Sc.

At Western Australian Department of Agriculture, Animal Health and Nutrition Laboratory, Nedlands, Western Australia—
Senior Research Officer—A. B. Beck, M.Sc.

At Institute of Agriculture, University of Western Australia, Nedlands, Western Australia—
Senior Research Officer—E. Munch-Petersen, M.Sc., B.A.

6. Division of Biochemistry and General Nutrition.

(Head-quarters: University of Adelaide.)

Chief—H. R. Marston, D.Sc., F.A.A., F.R.S.
Senior Principal Research Officer—D. S. Riceman, D.Sc., B.Ag.Sc., R.D.A.
Principal Research Officer—Miss M. C. Dawbarn, D.Sc.
Principal Research Officer—F. V. Gray, M.Sc.
Principal Research Officer—I. G. Jarrett, M.Sc.
Principal Research Officer—G. B. Jones, M.Sc.
Principal Research Officer—H. J. Lee, M.Sc.
Principal Research Officer—J. A. Mills, M.Sc., Ph.D.
Principal Research Officer—A. W. Peirce, D.Sc.
Senior Research Officer—Miss S. H. Allen, B.Sc.
Senior Research Officer—L. J. Frahn, M.Sc., Ph.D.
Senior Research Officer—A. F. Pilgrim, B.Sc.
Senior Research Officer—R. M. Smith, M.Sc.
Senior Research Officer—R. A. Weller, B.Sc.
Research Officer—W. W. Forrest, B.Sc., Ph.D.
Research Officer—R. E. Kuchel, B.Sc., R.D.A.
Research Officer—B. J. Potter, M.Sc.
Research Officer—Mrs. D. C. Roder, M.Sc.
Research Officer—D. J. Walker, B.Sc., Ph.D.
Senior Experimental Officer—D. W. Dewey.
Experimental Officer—A. C. Blaskett, B.Sc.
Experimental Officer—O. H. Filsell, B.Sc.
Experimental Officer—R. Hewett Jones, R.D.A.
Experimental Officer—W. S. Osborne White, B.Sc.
Experimental Officer—V. A. Stephen.
Experimental Officer—J. O. Wilson (part time).

7. Division of Building Research.

(Head-quarters: Graham-road, Highett, Victoria.)

Administration—
Chief—I. Langlands, M.Mech.E., B.E.E.
Technical Secretary—J. R. Barned, B.Sc., A.R.M.T.C.
Editor—I. C. H. Croll, B.Sc.(Hons.).

Information and Library—
Senior Research Officer—R. C. McTaggart, B.Sc.
Experimental Officer—E. M. Coulter, M.Ag.Sc.
Librarian—Miss L. W. Power.

Mechanics and Physics of Materials—
Senior Research Officer—F. A. Blakey, B.E.(Hons.), Ph.D.
Senior Research Officer—L. Finch, B.Arch., B.Sc., Ph.D.
Experimental Officer—F. D. Beresford, F.R.M.T.C.
Experimental Officer—B. Kroone, Chem. Drs.
Experimental Officer—R. E. Lewis, B.Sc.(Hons.).
Experimental Officer—B. C. Molony, A.F.T.C.
Experimental Officer—E. N. Mattison.
Experimental Officer—J. J. Russell, B.Sc.
Experimental Officer—W. H. Taylor, M.C.E.

Masonry Investigations—
Principal Research Officer—J. S. Hosking, M.Sc., Ph.D.
Senior Research Officer—H. V. Heuber, Dr.Phil.
Senior Research Officer—R. D. Hill, B.Sc., B.Com.
Research Officer—J. D. G. Hamilton, B.Sc.(Hons.).
Research Officer—Miss A. A. Milne, B.Sc., Ph.D.
Experimental Officer—D. N. Crook, A.Sw.T.C.
Experimental Officer—A. E. Holland, A.R.M.T.C.
Experimental Officer—Miss N. M. Rowland, F.R.M.T.C.

Mineralogical and Crystallographic Investigations—
Principal Research Officer—W. F. Cole, M.Sc., Ph.D.

Surfacing Materials Investigations—
Senior Research Officer—E. H. Waters, M.Sc.
Experimental Officer—J. E. Bright, B.Sc.
Experimental Officer—G. F. Moss, B.Sc.
Experimental Officer—D. A. Powell, B.Sc.
Experimental Officer—S. J. Way, B.Sc.

Architectural Physics—
Principal Research Officer—W. K. R. Lippert, Dr. rer. nat.
Principal Research Officer—R. W. Muncey, M.E.E.
Senior Research Officer—A. F. B. Nickson, M.Sc.
Research Officer—T. S. Holden, B.Sc.
Experimental Officer—W. A. Davern, A.R.M.T.C.
Experimental Officer—P. Dubout, B.Sc.
Experimental Officer—J. S. Howard, B.E.

Organic Materials Investigations—
Senior Research Officer—E. R. Ballantyne, B.Sc.
Research Officer—K. G. Martin, B.Sc.(Hons.).
Experimental Officer—N. G. Brown, A.R.M.T.C.
Experimental Officer—J. W. Spencer, B.Sc.

Fibrous Plaster Investigations—
Senior Research Officer—M. J. Ridge, M.Sc.
Experimental Officer—H. Surkevicius.

Paint on Plaster Investigations—
Senior Research Officer—E. Hoffmann, Dr.Phil.

8. CANBERRA LABORATORIES, ADMINISTRATIVE OFFICE.

(The services of this office are common to the Divisions and Sections in Canberra.)

Senior Administrative Officer—K. J. Prowse, J.P.
Deputy Senior Administrative Officer—D. Banyard.
Accountant—E. E. Petersen.
Scientific Librarian—D. R. May, B.A., B.Sc.
Senior Librarian—P. Russell.
Librarian—Miss C. J. Maguire, B.A.
Librarian—Miss M. J. Morley, B.A.

9. CHEMICAL RESEARCH LABORATORIES.

(Head-quarters: Lorimer-street, Fishermen's Bend, Victoria.)

Administration—
Director—I. W. Wark, D.Sc., Ph.D., F.A.A.
Divisional Secretary—W. E. Ewers, M.Sc.
Assistant Divisional Secretary—R. J. Davidson, B.Sc.

Division of Mineral Chemistry—
Chief—R. G. Thomas, B.Sc.
Senior Principal Research Officer—A. Walkley, M.A., D.Sc., Ph.D.
Principal Research Officer—R. C. Croft, M.Sc.
Principal Research Officer—F. K. McTaggart, M.Sc.
Principal Research Officer—I. E. Newnham, M.B.E., M.Sc.
Principal Research Officer—T. R. Scott, D.Sc., B.Ed.
Principal Research Officer—A. D. Wadsley, D.Sc.
Principal Research Officer—A. W. Wylie, D.Sc., Ph.D.
Senior Research Officer—D. F. A. Koch, B.Sc. (Hons.), Ph.D. (on leave).
Senior Research Officer—E. S. Pilkington, A.S.T.C.
Research Officer—K. J. Cathro, B.E., Ph.D.
Research Officer—H. J. Gardner, B.Sc., Ph.D.
Research Officer—A. F. Reid, M.Sc., Ph.D.
Research Officer—D. E. Scaife, B.Sc.(Hons.) (on leave).
Research Officer—A. G. Turnbull, B.Chem.Eng. (Hons.), M.Eng.Sc. (on leave).
Experimental Officer—Miss I. J. Bear, A.R.M.T.C.
Experimental Officer—B. M. Beattie, B.Sc.
Experimental Officer—L. J. Rogers, A.R.M.T.C.
Experimental Officer—Miss E. E. Rutherford, B.Sc.
Experimental Officer—H. R. Skewes, A.R.A.C.I.
Experimental Officer—P. R. Smith, A.R.M.T.C.

Cement and Ceramics Section—
Officer-in-charge—A. J. Gaskin, M.Sc.
Principal Research Officer—H. E. Vivian, B.Sc.Agr.
Principal Research Officer—G. F. Walker, B.Sc. (Hons.), Ph.D.
Senior Research Officer—K. M. Alexander, M.Sc., Ph.D.
Senior Research Officer—S. M. Brisbane, B.A., B.Sc., A.R.M.T.C. (on leave).
Senior Research Officer—H. Ellerton, F.Inst.Ceram. (at Bonython Research Laboratory, School of Mines, Adelaide).
Senior Research Officer—L. S. Williams, D.Phil., B.E.
Research Officer—G. M. Bruère, M.Sc.
Research Officer—J. Graham, M.Sc., Ph.D.
Research Officer—J. H. Taplin, B.Sc.(Hons.).
Experimental Officer—A. Adami, B.Chem.Eng.
Experimental Officer—Miss V. Anderlini, B.Sc.
Experimental Officer—P. J. Darragh, B.Sc.(Hons.).
Experimental Officer—C. E. S. Davis, B.Sc.(Hons.).
Experimental Officer—W. G. Garrett, A.R.M.T.C.
Experimental Officer—K. Grant, B.Sc.(Hons.).
Experimental Officer—R. R. Hughan.
Experimental Officer—Miss B. C. Terrell, B.Sc.
Experimental Officer—J. Wardlaw, B.Sc.(Hons.).
Experimental Officer—J. H. Weymouth, B.Sc.
Experimental Officer—J. D. Wolfe.

Foundry Sands Section—
Senior Research Officer—H. A. Stephens, B.Sc. (Hons.).
Experimental Officer—P. W. Goad, F.R.M.T.C.
Experimental Officer—A. N. Waterworth, A.H.T.C., A.R.M.T.C.

Division of Chemical Physics—
Chief—A. L. G. Rees, D.Sc., Ph.D., F.A.A.
Senior Principal Research Officer—J. M. Cowley, D.Sc., Ph.D.
Senior Principal Research Officer—A. Walsh, M.Sc.Tech., F.A.A.
Principal Research Officer—D. A. Davies, B.Sc. (Hons.).
Principal Research Officer—J. L. Farrant, M.Sc.
Principal Research Officer—J. Fridrichsons, M.Sc.
Principal Research Officer—A. C. Hurley, M.A., B.Sc., Ph.D.
Principal Research Officer—J. J. McNeill, M.Sc.
Principal Research Officer—A. McL. Mathieson, D.Sc., Ph.D.
Principal Research Officer—A. F. Moodie, B.Sc. (Hons.).
Principal Research Officer—J. D. Morrison, D.Sc., Ph.D.
Principal Research Officer—J. B. Willis, M.Sc., Ph.D.
Senior Research Officer—A. F. Beecham, B.Sc. (Hons.).
Senior Research Officer—C. Billington, B.A.
Senior Research Officer—C. K. Coogan, M.Sc., Ph.D. (on leave).
Senior Research Officer—B. Dawson, M.Sc., Ph.D.
Senior Research Officer—F. H. Dorman, M.A., M.Sc., Ph.D.
Senior Research Officer—N. S. Ham, M.Sc., Ph.D.
Senior Research Officer—G. R. Hercus, M.Sc., D.Phil.
Senior Research Officer—A. J. C. Nicholson, M.Sc., Ph.D.
Research Officer—J. O. Cope, M.Sc., Ph.D.
Research Officer—W. C. T. Dowell, M.Sc. (on leave).
Research Officer—J. Ferguson, M.Sc., Ph.D.
Research Officer—B. M. K. C. Gatehouse, M.Sc., Ph.D.
Research Officer—P. Goodman, M.Sc.
Research Officer—J. D. McLean, B.Sc.(Hons.), Ph.D.
Research Officer—E. G. McRae, M.Sc., Ph.D.
Research Officer—V. W. Maslen, M.Sc., D.Phil.
Research Officer—J. V. Sullivan, M.Sc. (at University of Western Australia, Perth).
Experimental Officer—G. F. H. Box.
Experimental Officer—E. E. Chakanovskis, Dip.Eng.
Experimental Officer—A. H. O'Rourke, Dip.Rad.Eng., A.R.M.T.C.
Experimental Officer—S. E. Powell.
Experimental Officer—D. L. Swingler, B.Sc.

Division of Physical Chemistry—

Chief—K. L. Sutherland, D.Sc., Ph.D., F.A.A.

Senior Principal Research Officer—S. D. Hamann, M.Sc., Ph.D. (At Department of Chemical Engineering, University of Sydney).

Principal Research Officer—J. A. Barker, B.A. (Hons.), D.Sc.

Principal Research Officer—I. Brown, B.Sc.(Hons.).

Principal Research Officer—V. A. Garten, D.Sc.

Principal Research Officer—W. W. Mansfield, B.Sc. (Hons.).

Principal Research Officer—D. E. Weiss, B.Sc.

Principal Research Officer—M. E. Winfield, D.Sc., Ph.D.

Senior Research Officer—H. G. David, B.Sc.(Hons.) (at Department of Chemical Engineering, University of Sydney).

Senior Research Officer—A. Ewald, B.Sc., Ph.D. (at Department of Chemical Engineering, University of Sydney).

Senior Research Officer—W. N. K. King, B.Sc.

Senior Research Officer—E. A. Swinton, B.Sc. (Hons.).

Senior Research Officer—R. G. Vines, M.Sc., B.Sc.

Research Officer—B. A. Bolto, B.Sc.(Hons.), Ph.D. (at Department of Inorganic Chemistry, Australian National University, Canberra).

Research Officer—R. B. Head, M.Sc., Ph.D.

Research Officer—A. R. King, B.Sc., Ph.D.

Research Officer—F. H. C. Stewart, Ph.D.

Research Officer—I. S. Walker, B.Sc., Ph.D.

Experimental Officer—L. F. Evans, A.S.M.B.

Experimental Officer—K. H. Eppinger, B.Sc.

Experimental Officer—W. Fock, B.Sc.

Experimental Officer—M. Linton, B.Sc.

Experimental Officer—R. McNeill, A.S.T.C.

Experimental Officer—E. F. McCoy, B.Sc.(Hons.) (at Department of Chemical Engineering, University of Sydney).

Experimental Officer—F. Smith, B.Sc.(Hons.).

Experimental Officer—Mrs. J. Wardlaw, B.Sc.

Organic Chemistry Section—

Officer-in-charge—H. H. Hatt, D.Sc., Ph.D.

Senior Principal Research Officer—J. R. Price, D.Sc., D.Phil., F.A.A.

Principal Research Officer—C. C. J. Culvenor, Ph.D., D.Phil.

Principal Research Officer—K. E. Murray, B.Sc. (Hons.).

Principal Research Officer—W. Zimmerman, D.Ing. (at University of Melbourne).

Senior Research Officer—C. S. Barnes, M.Sc., Ph.D.

Senior Research Officer—R. B. Bradbury, B.Sc., Ph.D. (at University of Adelaide).

Senior Research Officer—J. R. Cannon, M.Sc., Ph.D.

Senior Research Officer—W. D. Crow, M.Sc., Ph.D.

Senior Research Officer—L. K. Dalton, A.S.T.C.

Senior Research Officer—J. S. Fitzgerald, M.Sc., Ph.D.

Senior Research Officer—J. A. Lamberton, B.Sc., Ph.D.

Research Officer—D. T. Downing, B.Sc.(Hons.), Ph.D.

Research Officer—G. Kowala, B.Sc.(Hons.).

Research Officer—T. Mole, B.Sc.(Hons.), Ph.D.

Research Officer—B. P. Moore, B.Sc.(Hons.), Ph.D., D.Phil.

Research Officer—Miss D. J. Sutor, M.A., M.Sc. Ph.D. (seconded to Division of Chemical Physics).

Research Officer—P. C. Wailes, M.Sc., Ph.D.

Experimental Officer—B. D. Beilby, Dip.Appl.Chem., A.R.M.T.C.

Experimental Officer—Miss N. H. Corbett, B.Sc.

Experimental Officer—Mrs. H. C. Crowley, M.Sc.

Experimental Officer—Mrs. F. A. Doy, B.Sc.(Hons.).

Experimental Officer—Z. Kranz, Ind.Chem.

Experimental Officer—A. Meisters, Dip.Appl.Chem., A.R.M.T.C.

Experimental Officer—A. H. Redcliffe, Dip.Anal. Chem.

Experimental Officer—Mrs. I. Salivin, A.R.M.T.C.

Experimental Officer—L. W. Smith, B.Sc.

Experimental Officer—A. C. K. Triffett, A.R.M.T.C.

Chemical Engineering Section—

Officer-in-charge—H. R. C. Pratt, D.Sc., Ph.D.

Principal Research Officer—J. D. Blackwood, M.Sc., Ph.D.

Principal Research Officer—D. F. Kelsall, M.A.

Principal Research Officer—R. W. Urie, B.Sc., S.M.

Senior Research Officer—T. J. Birch, Chem.Eng., B.Sc.

Senior Research Officer—O. G. Ingles, B.A., M.Sc.

Senior Research Officer—A. B. Whitehead, B.Sc. (Hons.).

Research Officer—K. R. Hall, M.Sc.

Research Officer—L. S. Herbert, B.Sc.

Research Officer—W. Strauss, B.Chem.Eng., M.Sc., Ph.D.

Experimental Officer—P. Casamento, D.Chem.

Experimental Officer—A. J. Ingeme, A.R.M.T.C.

Experimental Officer—W. F. Krzandalsky, Dip.Ing., Dr.Techn.

Experimental Officer—J. C. H. McAdam, Dip.Appl. Chem., A.R.M.T.C.

Experimental Officer—C. J. Restarick, A.S.M.B.

Experimental Officer—A. J. Stedman, M.A.

Experimental Officer—B. W. Wilson, M.Sc.

Engineering Services—

Experimental Officer—S. J. Attwood, Dip.Mech.Eng.

Experimental Officer—J. B. Ross, B.Sc., A.R.M.T.C.

Library—

Scientific Librarian—Miss B. M. Brown, B.Sc.

Librarian—Mrs. D. E. Lamberton, B.A.

At Division of Electrotechnology—

Senior Research Officer—H. K. Welsh, M.Sc.

10. COAL RESEARCH SECTION.

(Head-quarters: Delhi-road, North Ryde, New South Wales.)

Officer-in-charge—H. R. Brown, B.Sc.(Eng.) (Hons.).

Technical Secretary—K. F. Baker, M.Sc.Appl., D.Sc.Tech.

Principal Research Officer—J. D. Brooks, B.Sc.(Hons.).

Principal Research Officer—E. J. Greenhow, B.Sc.(Hons.), Ph.D.

Principal Research Officer—M. F. R. Mulcahy, M.Sc., D.Phil.

Principal Research Officer—P. L. Waters, B.Sc.(Hons.), Ph.D., D.I.C.

Senior Research Officer—W. T. Cooper, B.Sc.(Hons.).

Senior Research Officer—R. A. Durie, M.Sc., Ph.D., D.I.C.

Senior Research Officer—J. S. Shannon, B.Sc.(Hons.), Ph.D., D.I.C.

Senior Research Officer—G. L. Shires, M.E.

Senior Research Officer—D. J. Swaine, M.Sc., Ph.D.

Research Officer—J. J. Batten, M.Sc., Ph.D., D.I.C.

Research Officer—K. McG. Bowling, B.Sc.(Hons.), Ph.D.

Research Officer—A. Cameron, B.Sc.(Hons.), Ph.D.

Research Officer—R. T. Harrisson, M.Sc., Ph.D.

Research Officer—W. R. Hesp, Dipl.Ing.Chem., D.Sc.Tech.

Research Officer—G. R. Hunt, M.Sc., Ph.D.

Research Officer—W. Kelly, B.Sc.(Hons.), Ph.D.

Research Officer—M. Kossenberg, Ph.D.

Research Officer—B. M. Lynch, M.Sc., Ph.D.

Research Officer—J. F. Stephens, M.Sc.

Research Officer—S. Sternhell, M.Sc. (on overseas studentship).
Research Officer—G. H. Taylor, M.Sc., Dr.rer.nat.
Research Officer—J. F. K. Wilshire, B.Sc.(Hons.), Ph.D.
Experimental Officer—F. Agus, A.M.Inst.F.
Experimental Officer—M. S. Burns, M.Inst.F.
Experimental Officer—Miss M. C. Clark, B.Sc., A.S.T.C.
Experimental Officer—A. C. Cook, B.A.
Experimental Officer—E. Glazmak, M.E.
Experimental Officer—P. R. C. Goard, B.Sc.
Experimental Officer—C. G. Macdonald, M.Sc.
Experimental Officer—R. J. Neronowicz, Dipl.Eng.
Experimental Officer—J. A. Nielson, B.E.(Mining).
Experimental Officer.—D. H. Philipp, B.Sc.
Experimental Officer—H. Silberman, B.Sc., Ph.D.
Experimental Officer—J. W. Smith.
Experimental Officer—W. O. Stacy, B.Sc.
Experimental Officer—Mrs. G. Sugowdz, M.Sc.
Experimental Officer—J. W. Sweeting, B.Sc.
Experimental Officer—J. Szewczyk, Dipl.Ing.Chem.
Experimental Officer—G. à Donau Szpindler, Dipl.Ing., D.I.C.
Experimental Officer—A. Watts, A.S.M.B.
Experimental Officer—D. J. Williams, B.Sc.(Hons.).
Librarian—Mrs. M. F. D. Beeke, Dipl.-Bibl.

11. Dairy Research Section.

(Head-quarters: Graham-road, Highett, Victoria.)

Officer-in-charge—G. Loftus Hills, B.Agr.Sc.
Technical Secretary—L. L. Muller, B.Sc.
Principal Research Officer—J. Czulak, B.Sc.(Agric.), Dip.Bact.
Principal Research Officer—N. King, M.Sc.
Senior Research Officer—J. Conochie, B.Sc.(Agric.).
Senior Research Officer—D. A. Forss, M.Sc.
Senior Research Officer—E. G. Pont, M.Sc.Agr.
Research Officer—J. W. Lee, Ph.D., B.Sc.(Hons.).
Experimental Officer—R. Beeby, A.R.M.T.C.
Experimental Officer—Miss B. M. P. Keogh, M.Sc.
Experimental Officer—A. J. Lawrence, B.Sc.

12. Editorial and Publications Section.

(Head-quarters: 314 Albert-street, East Melbourne.)

Editor—N. S. Noble, D.Sc.Agr., M.S., D.I.C.
Assistant Editor—A. E. Scott, M.Sc.
Senior Research Officer—R. W. Crabtree, B.Sc.
Senior Research Officer—Miss M. Walkom, B.A.
Research Officer—L. A. Bennett, B.Sc.
Research Officer—Miss L. F. Plunkett, B.Sc.
Research Officer—G. J. Wylie, B.A.(Hons.), B.Sc.
Experimental Officer—R. L. Aujard, B.Sc.
Experimental Officer—G. A. Forster, B.A., B.Sc.
Experimental Officer—R. Schoenfeld, B.Sc.

13. Division of Electrotechnology.

(Head-quarters: National Standards Laboratory at the University of Sydney.)

Chief of the Division—F. J. Lehany, M.Sc.
Senior Research Officer—R. C. Richardson, B.E. (overseas with A.S.L.O., London).
Senior Principal Research Officer—W. K. Clothier, B.Sc., M.E.
Senior Principal Research Officer—A. M. Thompson, B.Sc.
Principal Research Officer—J. S. Dryden, M.Sc., Ph.D., D.I.C.
Principal Research Officer—D. L. Hollway, B.E.E., M. EngSc., D.Sc.(Eng.).
Principal Research Officer—R. J. Meakins, B.Sc., Ph.D., D.I.C.
Senior Research Officer—L. G. Dobbie, M.E.
Senior Research Officer—D. L. H. Gibbings, B.E., B.Sc., Ph.D.

Senior Research Officer—D. G. Lampard, M.Sc., Ph.D.
Senior Research Officer—L. Medina, M.E., Dipl.Ing.
Senior Research Officer—T. M. Palmer, Dipl.F.H.
Senior Research Officer—D. W. Posener, M.Sc., Ph.D.
Senior Research Officer—H. K. Welsh, M.Sc.
Research Officer—G. J. A. Cassidy, B.E.E.
Research Officer—P. G. Harper, B.Sc.(Hons.), Ph.D.
Research Officer—G. J. Johnson, B.Sc.
Research Officer—C. H. Miller, B.E., D.Phil.
Research Officer—W. E. Smith, B.Sc.
Experimental Officer—R. W. Archer, A.S.T.C.
Experimental Officer—D. B. Armitage, B.Sc., B.E.
Experimental Officer—H. Bairnsfather.
Experimental Officer—F. C. Brown, A.S.T.C.
Experimental Officer—P. Buss, A.S.T.C.
Experimental Officer—J. C. Coles, B.A., A.S.T.C.
Experimental Officer—H. C. Collins, A.S.T.C.
Experimental Officer—J. S. Cook, M.Sc.
Experimental Officer—M. F. Currey, A.S.T.C.
Experimental Officer—A. W. Fleischmann, A.S.T.C.
Experimental Officer—J. Freiheiter, Dipl.Ing.
Experimental Officer—I. K. Harvey, A.S.T.C.
Experimental Officer—J. A. Harvey, B.Sc.
Experimental Officer—R. P. Hoffman, A.S.T.C.
Experimental Officer—R. E. Holmes, A.S.T.C.
Experimental Officer—D. F. P. Kelly, A.S.T.C.
Experimental Officer—A. J. Kopetsky, Dip.E.E.
Experimental Officer—M. C. McGregor, A.S.T.C.
Experimental Officer—L. M. Mandl, Dipl.Ing., A.S.T.C.
Experimental Officer—W. H. Reid, A.S.T.C.
Experimental Officer—H. A. Smith, A.S.T.C.
Experimental Officer—P. I. Somlo, Dipl.E.E.
Experimental Officer—K. G. Weir, A.S.T.C.

14. Engineering Section.

(Head-quarters: Graham-Road, Highett, Victoria.)

Officer-in-charge—R. N. Morse, B.Sc., B.E.
Electrical and Mechanical Engineer—F. G. Hogg, B.E.
Sectional Engineer—W. R. W. Read, Dip.Mech.Eng.
Senior Research Officer—Mrs. E. Kalecki, M.Sc.
Senior Research Officer—J. J. Kowalczewski, Dipl.Ing.
Senior Research Officer—M. Kovtrik, Ing.
Senior Research Officer—J. H. McClelland, M.Agr.Sc., B.Sc.
Senior Research Officer—P. A. Taylor, B.Sc.
Senior Research Officer—M. S. Walker, B.Mech.E., B.E.E.
Research Officer—R. H. S. Riordan, B.E.E.
Experimental Officer—L. G. Claxton, B.Mech.E., R.D.A.
Experimental Officer—D. W. Cunliffe, F.R.M.T.C.
Experimental Officer—J. T. Czarnecki, Dipl.Ing.
Experimental Officer—H. J. Griffiths, B.E.E., B.Sc.
Experimental Officer—R. C. R. Johnston, B.Mech.E., M.Eng.Sc.
Experimental Officer—K. A. Robeson, B.Mech.E.
Experimental Officer—G. T. Stephens, Dip.Mech.Eng., Dip.Elec.Eng.
Experimental Officer—E. R. Wilson, B.E.E., A.G.Inst.Tech.

15. Division of Entomology.

(Head-quarters: Canberra, A.C.T.)

At Canberra—

Administration—
Chief—A. J. Nicholson, D.Sc., F.A.A.
Assistant Chief—D. F. Waterhouse, D.Sc., F.A.A
Technical Secretary—K. L. Taylor, B.Sc.Agr.

Population Dynamics—
Chief—A. J. Nicholson, D.Sc., F.A.A.

Field Population Studies—
Principal Research Officer—L. R. Clark, M.Sc

Ecology of Orchard Pests—
Senior Research Officer—P. Geier, B.Sc.(Agr.), Ph.D.
Experimental Officer—A. Magassy, Dr.Agr.Sc.

Cockchafers and Eucalypt Defoliating Insects—
Senior Research Officer—P. B. Carne, B.Agr.Sc., Ph.D., D.I.C.

Locust Investigations—
Principal Research Officer—K. H. L. Key, D.Sc., Ph.D., D.I.C., F.A.A.

Grasshopper Investigations—
Research Officer—D. P. Clark, B.Sc., Ph.D.

Pasture Caterpillars and Taxonomy of Lepidoptera—
Principal Research Officer—I. F. B. Common, M.A., M.Agr.Sc.

Taxonomy of Diptera—
Senior Research Officer—S. J. Paramonov, D.Sc.

Taxonomy of Hymenoptera—
Principal Research Officer—E. F. Riek, M.Sc.

Museum—
Curator—K. H. L. Key, D.Sc., Ph.D., D.I.C., F.A.A.
Research Officer—T. G. Campbell.

Physiology and Toxicology—
Assistant Chief—D. F. Waterhouse, D.Sc., F.A.A.
Principal Research Officer—D. Gilmour, M.Sc.
Principal Research Officer—R. H. Hackman, M.Sc., Ph.D.
Senior Research Officer—R. F. Powning, A.S.T.C., M.Sc.
Research Officer—L. B. Barton Browne, B.Sc., Ph.D.
Research Officer—A. R. Gilby, M.Sc., Ph.D.
Experimental Officer—Mrs. M. M. Goldberg, B.Sc.
Experimental Officer—H. Irzykiewicz.
Experimental Officer—J. W. McKellar, B.Sc.

Virus Investigations—
Senior Principal Research Officer—M. F. Day, B.Sc., Ph.D., F.A.A.
Research Officer—T. D. C. Grace, B.Sc.
Experimental Officer—N. E. Grylls, D.D.A.

Insecticide Investigations—
Senior Research Officer—R. W. Kerr, B.Sc.

Biological Control—
Principal Research Officer—F. Wilson.
Research Officer—G. F. Bornemissza, Ph.D.

Termite Investigations—
Principal Research Officer—F. J. Gay, B.Sc., D.I.C.

Termites in Forest Trees—
Senior Research Officer—T. Greaves.

Grain Storage Investigations—
Principal Research Officer—S. W. Bailey, B.Sc., A.R.C.S. (overseas).

Sheep Blowfly Ecology—
Principal Research Officer—K. R. Norris, M.Sc.

At Yeerongpilly, Queensland—

Cattle Tick Investigations—
Senior Research Officer—W. J. Roulston, M.Sc.
Senior Research Officer—P. R. Wilkinson, M.A.
Experimental Officer—H. J. Schnitzerling, Dip.Ind.Chem.
Experimental Officer—C. A. Schuntner, B.Sc.
Experimental Officer—B. F. Stone, Dip.Ind.Chem.

At Ingham, Queensland—

Cattle Tick Investigations—
Experimental Officer—K. L. S. Harley, B.Sc.

At Plant and Soils Laboratory, Brisbane—

Biological Control Investigations—
Senior Research Officer—G. O. Stride, B.Sc., Ph.D.

At Nedlands, Western Australia—

Earth Mite and Lucerne Flea Investigations—
Senior Research Officer—M. M. H. Wallace, B.Sc.

At Sydney—

Biological Control—
Senior Research Officer—G. J. Snowball, B.Sc.
Research Officer—T. G. Campbell.
Experimental Officer—R. G. Lukins, B.Sc. (in Hawaii).

Fruit Fly Ecology (with University of Sydney)—
Research Officer—M. A. Bateman, B.Sc., Ph.D.

16. DIVISION OF FISHERIES AND OCEANOGRAPHY.

(Head-quarters: Cronulla, N.S.W.)

At Cronulla—
Chief—G. F. Humphrey, M.Sc., Ph.D.
Administrative Officer—G. R. Williams, B.Ec.
Technical Secretary—Mrs. L. M. Willings, B.A. (Hons.).
Librarian—Miss A. M. Copeland, B.A.(Hons.).
Research Fellow—L. G. M. Baas Becking, Ph.D., D.Sc. (with Bureau of Mineral Resources, Canberra).
Principal Research Officer—B. V. Hamon, B.Sc. (Hons.), B.E.(Hons.).
Principal Research Officer—I. S. R. Munro, M.Sc.
Principal Research Officer—D. J. Rochford, B.Sc. (Hons.).
Principal Research Officer—J. M. Thomson, D.Sc.
Principal Research Officer—E. J. F. Wood, B.A., M.Sc.
Senior Research Officer—A. D. Brown, M.Sc., Ph.D.
Senior Research Officer—K. Wyrtki, Dr.Nat.Sci.
Research Officer—R. G. Chittleborough, M.Sc., Ph.D.
Research Officer—Miss S. W. Jeffrey, M.Sc., Ph.D.
Research Officer—D. E. Kurth, B.Sc.(Hons.) (overseas).
Research Officer—W. J. R. Lansing, D.Sc.
Research Officer—R. J. MacIntyre, M.Sc. (overseas).
Research Officer—W. B. Malcolm, B.Sc., Ph.D. (overseas).
Research Officer—B. S. Newell, M.Sc.
Research Officer—J. P. Robins, B.Sc.
Research Officer—D. J. Tranter, M.Sc.
Research Officer—H. B. Wisely, M.Sc.(Hons.).
Experimental Officer—J. B. S. Bohanna, B.Sc.Agr.
Experimental Officer—N. L. Brown, A.S.T.C.
Experimental Officer—A. D. Crooks, B.Sc.
Experimental Officer—H. R. Jitts, B.Sc.

At Melbourne—
Research Officer—T. R. Cowper, B.Sc.(Hons.).

At Perth—
Senior Research Officer—K. Sheard, D.Sc.

At Hobart—
Principal Research Officer—A. G. Nicholls, B.Sc. (Hons.), Ph.D.
Senior Research Officer—A. M. Olsen, M.Sc.

At Thursday Island, Queensland—
Senior Research Officer—J. S. Hynd, B.Sc.(Hons.).

17. FODDER CONSERVATION SECTION.

(Head-quarters: Graham-road, Highett, Victoria.)

Officer-in-charge—W. L. Greenhill, M.E.
Principal Research Officer—G. W. Lanigan, M.Sc.
Senior Research Officer—Mrs. J. F. Melvin, M.Sc.
Research Officer—W. Shepherd, B.Sc., B.Agr.Sc.
Research Officer—Beulah Simpson, B.Sc., Ph.D.
Experimental Officer—C. J. Brady, M.Sc.Agr.
Experimental Officer—J. de Freitas, F.R.M.T.C.

18. Division of Food Preservation and Transport.

(Head-quarters: State Abattoir, Homebush Bay, New South Wales.)

At Homebush, New South Wales—

Administration—
Chief—J. R. Vickery, M.Sc., Ph.D.
Technical Secretary—R. B. Withers, M.Sc., Dip.Ed.

Scientific Services—
Scientific Librarian—Miss B. E. Johnston, B.Sc.
Experimental Officer—Miss E. M. Christie, B.Sc.
Experimental Officer—R. J. North, B.Sc. (at Sydney University).

Physics and Transport Section—
Senior Principal Research Officer—E. W. Hicks, B.A., B.Sc.
Senior Research Officer—M. C. Taylor, M.Sc.
Research Officer—H. L. Evans, M.Sc. (overseas).
Experimental Officer—N. D. Cowell, B.Sc.(Hons.).
Experimental Officer—J. D. Mellor.
Experimental Officer—Mrs. W. Szulmayer, Dipl.Phys.

Microbiology Section—
Senior Principal Research Officer—W. J. Scott, B.Agr.Sc., D.Sc.
Senior Research Officer—W. G. Murrell, B.Sc.Agr., D.Phil.
Research Officer—J. H. B. Christian, B.Sc.Agr. (Hons.), Ph.D.
Experimental Officer—B. J. Bloomfield, B.Sc. (Hons.).
Experimental Officer—Miss B. J. Marshall, A.S.T.C.
Experimental Officer—D. F. Ohye, D.I.C.
Experimental Officer—Miss J. A. Waltho, A.S.T.C.
Experimental Officer—A. D. Warth, B.Sc.

Biochemistry Investigations—
Principal Research Officer—F. E. Huelin, B.Sc. (Hons.), Ph.D.
Research Officer—J. B. Davenport, M.Sc.
Experimental Officer—B. H. Kennett, A.S.T.C.

Organic Chemistry Investigations—
Principal Research Officer—Miss T. M. Reynolds, M.Sc., D.Phil.
Senior Research Officer—E. F. L. J. Anet, M.Sc., Ph.D.
Research Officer—D. L. Ingles, M.Sc., Ph.D.
Experimental Officer—Miss D. E. Fenwick, A.S.T.C.

Muscle Biochemistry Investigations—
Principal Research Officer—R. P. Newbold, M.Sc., Ph.D.
Experimental Officer—C. A. Lee, B.Sc. (at Brisbane).

Fruit and Vegetable Storage Section—
Principal Research Officer—E. G. Hall, B.Sc.Agr. (Hons.).
Research Officer—Miss J. M. Bain, M.Sc.

Canning and Fruit Products Section—
Senior Principal Research Officer—L. J. Lynch, B.Agr.Sc.(Hons.).
Principal Research Officer—J. F. Kefford, M.Sc.
Senior Research Officer—B. V. Chandler, B.Sc. (Hons.), Ph.D.
Senior Research Officer—E. G. Davis, B.Sc.(Hons.).
Senior Research Officer—R. S. Mitchell, M.Sc.Agr.
Research Officer—P. W. Board, B.Sc.(Hons.).
Research Officer—D. J. Casimir, M.Sc., Dip.Ed.
Experimental Officer—K. A. Harper, B.Sc., A.S.T.C.

Dried Foods Section—
Senior Research Officer—D. McG. McBean, B.Sc.
Experimental Officer—A. A. Johnson, A.S.T.C.

Fish Preservation Investigations—
Principal Research Officer—W. A. Empey, B.V.Sc.
Experimental Officer—W. A. Montgomery, A.S.T.C.

Egg Investigations—
Chief—J. R. Vickery, M.Sc., Ph.D.
Experimental Officer—F. S. Shenstone, A.S.T.C.

Freezing of Fruit and Vegetables—
Senior Research Officer—J. Shipton, B.Sc.Agr.
Research Officer—J. H. Scheltema, M.Sc.
Experimental Officer—J. H. Last, A.S.T.C.

Food Irradiation Investigations—
Research Officer—J. J. MacFarlane, M.Sc.

At Auburn, New South Wales—

Meat Dehydration Investigations—
Senior Research Officer—A. R. Prater, B.Sc.Agr.
Experimental Officer—R. G. P. Elbourne, A.S.T.C.

At Botany School, University of Sydney—

Plant Physiology Investigations—
Chief Research Officer—R. N. Robertson, B.Sc., Ph.D., F.A.A. (overseas).
Senior Research Officer—A. B. Hope, B.Sc.(Hons.), Ph.D.
Senior Research Officer—H. S. McKee, B.A., D.Phil.
Senior Research Officer—J. F. Turner, M.Sc., Ph.D.
Senior Research Officer—Mrs. D. H. Turner, M.Sc., Ph.D.
Research Officer—M. D. Hatch, B.Sc.(Hons.), Ph.D.
Experimental Officer—Miss J. E. King, B.Sc.
Experimental Officer—Miss Rosemary F. Mullens, B.Sc.(Hons.).
Experimental Officer—J. Smydzuk, Ing. of Ch.
Experimental Officer—N. F. B. Tobin, B.Sc.(Hons.).

At Botany School, University of Melbourne—

Plant Physiology Investigations—
Senior Research Officer—K. S. Rowan, M.Sc., Ph.D. (overseas).

At Biochemistry School, University of Sydney—

Physical Chemistry Section—
Experimental Officer—Miss J. F. Back, B.Sc., Dip.Ed.
Experimental Officer—Miss K. O. Kelly, B.Sc.
Experimental Officer—M. B. Smith, A.S.A.S.M., B.Sc.

At Tasmanian Regional Laboratory, Hobart—

Processing of Fruit and Vegetables—
Senior Experimental Officer—S. M. Sykes, B.Sc.Agr.
Experimental Officer—R. A. Gallop, A.S.T.C. (on leave).

At Cannon Hill, Queensland—

Meat Investigations—
Officer-in-charge—A. Howard, M.Sc.
Senior Research Officer—G. Kaess, Dr.Ing.
Research Officer—C. A. McChesney, B.Sc., Ph.D.
Experimental Officer—P. E. Bouton, B.Sc.
Experimental Officer—M. F. Meaney, B.Sc.(Hons.).
Experimental Officer—N. T. Russell, D.I.C.
Experimental Officer—J. F. Weidemann, B.Sc.

19. Division of Forest Products.

(Head-quarters: 69 Yarra Bank-road, South Melbourne, Victoria.)

Administration—
Chief—S. A. Clarke, B.E.
Assistant Chief—C. S. Elliott, B.Sc.
Assistant Chief—H. E. Dadswell, D.Sc.
Technical Secretary—F. A. Priest, A.S.A.S.M.
Information Officer—A. P. Wymond, M.Sc.
Scientific Librarian—Miss M. I. Hulme.
Librarian—Miss A. Forbes.
Senior Experimental Officer—L. Santer, M.Mech.E., Dip.Ing.

Wood and Fibre Structure Section—

Assistant Chief—H. E. Dadswell, D.Sc.
Senior Principal Research Officer—A. B. Wardrop, D.Sc., Ph.D.
Senior Research Officer—Miss M. M. Chattaway, M.A., B.Sc., D.Phil.
Senior Research Officer—W. E. Hillis, M.Sc., A.G.Inst.Tech.
Senior Research Officer—H. D. Ingle, B.For.Sc.
Research Officer—J. Cronshaw, B.Sc., Ph.D.
Experimental Officer—Miss A. Carle, B.Sc., A.G.Inst.Tech.
Experimental Officer—G. W. Davies, B.Sc.
Experimental Officer—J. W. P. Nicholls, B.Sc.

Wood Chemistry Section—

Assistant Chief—H. E. Dadswell, D.Sc.
Principal Research Officer—D. E. Bland, M.Sc.
Principal Research Officer—H. G. Higgins, B.Sc. (Hons.).
Principal Research Officer—R. C. McK. Stewart, B.Sc.
Senior Research Officer—A. J. Watson, A.R.M.T.C.
Experimental Officer — Miss V. Goldsmith, A.R.M.T.C.
Experimental Officer—G. Kocins, A.R.M.T.C.
Experimental Officer—A. W. McKenzie, A.R.M.T.C.
Experimental Officer—F. H. Phillips, A.R.M.T.C.
Experimental Officer—Mrs. M. Szilagyi, Dip.Ind. Chem.
Experimental Officer—J. L. de Yong, B.Sc.

Paper Stability—

Senior Principal Research Officer—W. E. Cohen, D.Sc.

Timber Physics Section—

Principal Research Officer—R. S. T. Kingston, B.Sc., B.E.
Principal Research Officer—L. N. Clarke, M.Mech.E., B.Eng.Sc.
Senior Research Officer—G. N. Christensen, M.Sc., Ph.D.
Research Officer—P. U. A. Grossman, M.Sc., Ph.A.Mr., Ph.D.
Research Officer—Miss K. E. Kelsey, M.Sc. (on study leave).
Experimental Officer—L. D. Armstrong, A.R.M.T.C.
Experimental Officer—D. R. Callow, B.E.
Experimental Officer—N. C. Edwards, A.S.M.B.
Experimental Officer—H. F. A. Hergt, A.R.M.T.C.
Experimental Officer—J. Rozulapa, Dipl.Phys.

Timber Mechanics Section—

Principal Research Officer—J. D. Boyd, M.C.E.
Principal Research Officer—N. H. Kloot, M.Sc.
Principal Research Officer—R. G. Pearson, B.A., B.C.E.
Experimental Officer—R. N. Bournon.
Experimental Officer—J. J. Mack, A.R.M.T.C.
Experimental Officer—Miss A. Ryan, A.R.M.T.C.
Experimental Officer—K. B. Schuster, A.R.M.T.C.

Timber Preservation Section—

Senior Principal Research Officer—N. Tamblyn, M.Sc.(Agric.).
Principal Research Officer—E. W. B. DaCosta, M.Agr.Sc.
Senior Research Officer—E. L. Ellwood, M.Sc. (overseas).
Senior Research Officer—R. Johanson, M.Sc.
Research Officer — P. Rudman, B.Sc., Ph.D., Dip.Microbiol.
Senior Experimental Officer—F. A. Dale, Dip.Mech.E.
Experimental Officer—J. E. Barnacle, Dip.Mech.E., Dip.E.E.
Experimental Officer—J. Beesley, Dip.For., M.Sc. (For.).
Experimental Officer—D. F. McCarthy, A.R.M.T.C.
Experimental Officer—N. E. M. Walters, B.Sc.

Timber Seasoning Section—

Senior Principal Research Officer—G. W. Wright, M.E.
Research Officer—W. G. Kauman, B.Sc., Dr. en Sc., A.R.M.T.C.
Experimental Officer—L. J. Brennan.
Experimental Officer—G. S. Campbell.
Experimental Officer—R. H. Capes, B.E.
Experimental Officer—F. J. Christensen, A.R.M.T.C.
Experimental Officer—W. R. Finighan, A.R.M.T.C.
Experimental Officer—K. W. Fricke, Assoc.Aero.Eng.
Experimental Officer—R. M. Liversidge, A.R.M.T.C.

Plywood Investigations Section—

Principal Research Officer—J. W. Gottstein, B.Sc.
Experimental Officer—K. Hirst, Dip.Mech.E.
Experimental Officer—P. J. Moglia, Dip.Mech.E.
Experimental Officer—A. Stashevski, Dip.For.Eng.

Timber Utilization Section—

Senior Principal Research Officer—R. F. Turnbull, B.E.
Senior Research Officer—W. M. McKenzie, M.Sc. (For.) (overseas).
Senior Research Officer—K. F. Plomley, B.Sc.(Agric.).
Experimental Officer—R. L. Cowling, Dip.Mech.E., Dip.E.E.
Experimental Officer—D. S. Jones, B.C.E.
Experimental Officer—M. W. Page.
Experimental Officer—R. K. Profitt, Dip.App.Sc.

20. INDUSTRIAL RESEARCH LIAISON SECTION.

(Head-quarters: 314 Albert-street, East Melbourne, Victoria.)

Officer-in-charge—L. Lewis, B.Met.E.
Senior Research Officer—J. P. Shelton, M.Sc., A.B.S.M.
Senior Research Officer—J. F. H. Wright, B.Sc.
Experimental Officer—J. D. Dover, A.S.T.C.

21. IRRIGATION RESEARCH STATIONS.

(Head-quarters: Merbein, Victoria.)

Senior Officer-in-charge—F. Penman, M.Sc.

At Commonwealth Research Station, Merbein (Murray Irrigation Areas)—

Officer-in-charge—F. Penman, M.Sc.
Principal Research Officer—J. G. Baldwin, B.Agr.Sc., B.Sc.
Research Officer—D. McE. Alexander, B.Sc.
Research Officer—A. J. Antcliff, B.Sc.(Hons.).
Research Officer—A. F. Bird, M.Sc., Ph.D. (at University of Adelaide).
Research Officer—S. F. Bridley, B.Agr.Sc.
Research Officer—M. R. Sauer, B.Agr.Sc.
Research Officer—J. V. Seekamp, B.Agr.Sc. (part-time).
Research Officer—W. J. Webster, B.Sc.
Research Officer—R. C. Woodham, B.Agr.Sc.
Experimental Officer—C. A. Argyriadis, M.S.A.E.
Experimental Officer—D. G. M. Blair, B.Agr.Sc.
Experimental Officer—P. May, Ing.Agr.
Experimental Officer—N. C. Permezel, B.Sc.(Hons.).
Library Assistant—Miss E. A. Stone, B.A.(Hons.).

At Irrigation Research Station, Griffith (Murrumbidgee Irrigation Areas)—

Officer-in-charge—E. R. Hoare, B.Sc.
Senior Research Officer—C. T. Gates, M.Agr.Sc.
Senior Research Officer—E. N. S. Trickett, B.Sc. (Eng.)(Hons.).
Research Officer—D. Bouma, Ir.Agr.
Research Officer—H. Groenewegen, Ir.Agr.
Research Officer—T. Talsma, Ir.Agr.
Administrative Officer—J. F. Donovan, B.Ec.
Librarian—Miss M. Russell.

22. DIVISION OF LAND RESEARCH AND REGIONAL SURVEY.

(Head-quarters: Canberra, A.C.T.)

At Head-quarters—
Chief—C. S. Christian, B.Agr.Sc., M.S.
Assistant to the Chief—A. F. Gurnett-Smith, B.Agr.Sc.
Technical Secretary—Miss M. M. Mills, B.Sc.(Hons.)
Principal Research Officer—E. Phillis, Ph.D., D.Sc.

Regional Land Surveys—
Principal Research Officer—G. A. Stewart, M.Agr.Sc.

Ecology and Forest Botany—
Senior Research Officer—R. A. Perry, M.Sc.
Senior Research Officer—N. H. Speck, Ph.D., M.Sc., B.A.
Senior Research Officer—R. Story, D.Sc.
Research Officer—R. G. Robbins, Ph.D., M.Sc.
Experimental Officer—J. C. Saunders, B.Sc.Agr.

Geomorphology—
Senior Research Officer—J. A. Mabbutt, M.A. (Hons.).
Research Officer—R. W. Galloway, M.A.(Hons.), Ph.D.
Research Officer—E. J. A. T. Reiner, Dr.rer.nat.
Research Officer—R. L. Wright, M.Sc.

Pedology—
Senior Research Officer—H. A. Haantjens, Ing.Agr.
Research Officer—W. H. Litchfield, B.Sc.Agr. (seconded from Division of Soils).
Research Officer—G. K. Rutherford, M.Sc., Dip.Ag., Ph.D.

Systematic Botany—
Senior Research Officer—R. D. Hoogland, D.Sc.
Experimental Officer—M. Lazarides, Q.D.A.

Climatology—
Senior Research Officer—R. O. Slatyer, M.Sc.(Agr.).
Research Officer—J. C. Turner, B.Sc.Agr.(Hons.).
Experimental Officer—Miss J. M. Arnold, B.Sc.

Hydrology—
Research Officer—T. G. Chapman, B.Sc.(Hons.), Ph.D.

Agricultural Ecology—
Research Officer—J. J. Basinski, B.Sc., M.A.

Regional Research Stations—

At Katherine Research Station, Northern Territory—
Senior Research Officer—W. Arndt, B.Agr.Sc.
Senior Research Officer—M. J. T. Norman, B.Sc. (Hons.), Ph.D.
Research Officer—R. Wetselaar, Ing.Agr.

At Kimberley Research Station, Western Australia—
Experimental Officer—A. L. Chapman, B.Agr.Sc.
Experimental Officer—E. C. B. Langfield.
Experimental Officer—N. J. P. Thomson, B.Agr.Sc.

At Alice Springs, Northern Territory—
Experimental Officer—R. E. Winkworth, B.Sc. (Hons.).

At Coastal Plains Research Station, Northern Territory—
Experimental Officer—J. D. Moir, M.A.

23. MATHEMATICAL INSTRUMENTS SECTION.

(Head-quarters: Department of Electrical Engineering, University of Sydney.)

Officer-in-charge—Professor D. M. Myers, B.Sc., D.Sc.Eng.

24. DIVISION OF MATHEMATICAL STATISTICS.

(Head-quarters: University of Adelaide.)

At Head-quarters, Adelaide—
Chief—E. A. Cornish, B.Agr.Sc., D.Sc., F.A.A.
Research Officer—A. G. Constantine, B.Sc.(Hons.).
Research Officer—G. N. Wilkinson, M.Sc.
Experimental Officer—K. M. Cellier, B.Sc.
Experimental Officer—Miss M. J. Evans, B.A.
Experimental Officer—J. P. Penny, B.Sc.
Experimental Officer—L. G. Veitch, B.Sc.

At Division of Animal Health and Production, Prospect, New South Wales—
Research Officer—H. Weiler, Lic.ès.Sc., M.Sc.

At Division of Building Research, Highett, Victoria—
Senior Research Officer—R. Birtwistle, B.Sc.

At Division of Food Preservation and Transport, Homebush, New South Wales—
Senior Research Officer—G. G. Coote, B.A., B.Sc.
Experimental Officer—E. A. Roberts, B.Sc.Agr.

At Division of Forest Products, Melbourne—
Research Officer—W. R. Flower, B.Sc., B.A.(Hons.).
Experimental Officer—Miss N. Ditchburne.

At Division of Plant Industry, Brisbane—
Research Officer—K. P. Haydock, B.Sc.(Hons.).

At Division of Plant Industry, Canberra—
Senior Principal Research Officer—G. A. McIntyre, B.Sc.(Hons.), Dip.Ed.
Research Officer—M. L. Dudzinski, B.Sc., B.Ec. (Hons.).

At Regional Pastoral Laboratory, Armidale, New South Wales—
Research Officer—P. F. May, B.Sc.Agr.(Hons.).

At University of Melbourne, School of Agriculture—
Research Officer—A. M. W. Verhagen, Cand.Nat. Phil., B.A.(Hons.).

At University of Melbourne, Computation Laboratory—
Principal Research Officer—T. Pearcey, B.Sc.
Senior Research Officer—G. W. Hill, M.Sc.

At Western Australian Regional Laboratory, Perth—
Senior Research Officer—N. S. Stenhouse, B.Sc.
Experimental Officer—C. A. P. Boundy, B.E.

At Wool Research Laboratories, Division of Protein Chemistry, Melbourne—
Research Officer—W. B. Hall, B.A.

25. DIVISION OF METEOROLOGICAL PHYSICS.

(Head-quarters: Station-street, Aspendale, Victoria.)

Chief—C. H. B. Priestley, M.A., Sc.D., F.A.A.
Senior Principal Research Officer—E. L. Deacon, B.Sc.
Senior Principal Research Officer—W. C. Swinbank, M.Sc.
Principal Research Officer—A. F. A. Berson, Dr.Phil.
Principal Research Officer—R. J. Taylor, B.Sc.
Senior Research Officer—R. H. Clarke, B.A., B.Sc.
Senior Research Officer—A. J. Dyer, M.Sc., Ph.D.
Senior Research Officer—I. C. McIlroy, B.Sc.
Senior Research Officer—E. K. Webb, B.A.(Hons.), B.Sc.
Research Officer—F. K. Ball, B.Sc.(Hons.).
Research Officer—J. P. Funk, Dr.Phil.
Experimental Officer—D. E. Angus, B.Sc. (overseas).
Experimental Officer—N. E. Bacon, B.Sc.
Experimental Officer—B. G. Collins, B.Sc.
Experimental Officer—R. R. McGregor, Dip.Appl.Sc.
Experimental Officer—F. J. Maher, A.R.M.T.C.
Experimental Officer—C. J. Sumner, A.M.S.E.
Experimental Officer—A. J. Troup, B.Sc.
Experimental Officer—Miss S. A. Yeo, B.Sc.

26. DIVISION OF METROLOGY.

(Head-quarters: National Standards Laboratory at University of Sydney.)

Administration—
- Chief—N. A. Esserman, B.Sc.
- Divisional Administrative Officer—J. Hanna.

Length Section—
- Principal Research Officer—M. J. Puttock, B.Sc. (Eng.).
- Senior Research Officer—Miss M. G. I. Pearce, M.Sc.
- Research Officer—P. J. Sim, B.Sc., B.E.
- Research Officer—E. G. Thwaite, B.Sc.
- Senior Experimental Officer—R. H. Furniss, A.S.T.C.
- Experimental Officer—J. W. Bell.
- Experimental Officer—Miss M. C. Dive, B.Sc.
- Experimental Officer—Miss P. M. Yelland.

Mass Section—
- Principal Research Officer—G. A. Bell, B.Sc.
- Research Officer—I. F. Mayer, B.Sc., B.E.
- Experimental Officer—A. L. Clarke, B.Sc.
- Experimental Officer—E. Grunwald, Dip.Ing.
- Experimental Officer—J. W. Humphries, B.Sc.

Interferometry Section—
- Principal Research Officer—C. F. Bruce, D.Sc.
- Senior Research Officer—H. J. Ritter, Dr.rer.nat. math.
- Research Officer—P. E. Ciddor, M.Sc.
- Research Officer—R. M. Hill, Ph.D.
- Experimental Officer—R. S. Fisher, A.R.M.T.C.

Electronics Section—
- Senior Research Officer—H. A. M. Ross, A.S.T.C.
- Experimental Officer—J. L. Goldberg, B.Sc., B.E.

Applied Mechanics Section—
- Senior Principal Research Officer—C. A. Gladman, B.Sc.(Eng.).
- Principal Research Officer—J. A. Macinante, B.E., A.S.T.C.
- Senior Research Officer—G. Lorenz, Dipl.Ing.Eth.
- Research Officer—R. F. Scrutton, M.Sc.
- Experimental Officer—B. H. P. Cresswell, A.S.T.C.
- Experimental Officer—K. Edensor, A.S.T.C.
- Experimental Officer—R. J. Ellis, B.E.
- Experimental Officer—D. H. Fox.
- Experimental Officer—A. A. V. Gibson, A.S.T.C.
- Experimental Officer—J. Waldersee, B.Sc.
- Experimental Officer—R. A. Williams, B.M.E. (Hons.).

Divisional Services—
Drawing Office—
- Experimental Officer—I. A. Rey, A.S.T.C.

27. MINERAGRAPHIC INVESTIGATIONS.

(Head-quarters: University of Melbourne.)

Officer-in-charge—A. B. Edwards, D.Sc., Ph.D., D.I.C.
Principal Research Officer—G. Baker, D.Sc.
Principal Research Officer—J. McAndrew, M.Sc., Ph.D.
Research Officer—I. M. Threadgold, B.Sc.
Research Officer—R. H. Vernon, M.Sc.
Research Officer—K. L. Williams, M.Sc.
Experimental Officer—A. W. Hounslow, F.R.M.T.C.

28. NATIONAL STANDARDS LABORATORY.

Director—N. A. Esserman, B.Sc.

(The services shown hereunder are common to the Divisions of Metrology, Electrotechnology, and Physics, housed in the Laboratory at the University of Sydney.)

Clerical—
- Chief Clerk—F. J. Whitty, A.A.S.A., A.C.I.S., J.P.
- Accountant—T. C. Clark, A.A.S.A.

Library—
- Scientific Librarian—Miss M. McKechnie, B.A.
- Scientific Librarian—Miss R. E. Moulden, B.Sc., Dip.Ed.
- Senior Librarian—Miss J. M. Cook, B.A.(Hons.)
- Librarian—Miss P. I. Ross, B.A.(Hons.).

29. ORE-DRESSING INVESTIGATIONS.

(Head-quarters: University of Melbourne.)

Officer-in-charge—Associate Professor H. H. Dunkin, B.Met.E.
Principal Research Officer—K. S. Blaskett, B.E.
Senior Research Officer—S. B. Hudson, M.Sc.
Senior Research Officer—J. T. Woodcock, B.Met.E., M.Eng.Sc.
Experimental Officer—F. D. Drews.
Experimental Officer—J. S. Henkel, B.Met.E.
Experimental Officer—G. W. Heyes, Dipl.Met.
Experimental Officer—Miss J. Richardson, B.Sc.
Experimental Officer—W. J. Trahar, B.Sc.

30. PHYSICAL METALURGY SECTION.

(Head-quarters: University of Melbourne.)

Officer-in-charge—Professor H. W. Worner, D.Sc.
Principal Research Officer—R. C. Gifkins, B.Sc.
Research Officer—D. R. Miller, M.Sc., Ph.D. (on leave).
Research Officer—J. W. Suiter, M.Sc., Ph.D.
Experimental Officer—J. A. Corbett, A.M.A.I.M.M.
Experimental Officer—H. F. Ryan, B.Sc.

31. DIVISION OF PHYSICS.

(Head-quarters: National Standards Laboratory at the University of Sydney.)

Chief—R. G. Giovanelli, D.Sc.
Laboratory Secretary—A. G. Driver, B.Sc.
Hon. Research Fellow—G. H. Briggs, D.Sc., Ph.D.
Research Fellow—J. M. Beckers, M.Sc.
Senior Principal Research Officer—A. F. A. Harper, M.Sc.
Principal Research Officer—W. R. G. Kemp, B.Sc.
Principal Research Officer—P. G. Klemens, M.Sc., D.Phil.
Principal Research Officer—W. H. Steel, B.A., Dr.ès.Sc.
Principal Research Officer—G. K. White, M.Sc., D.Phil.
Principal Research Officer—R. G. Wylie, M.Sc., Ph.D.
Senior Research Officer—G. S. Bogle, M.A., D.Phil., M.Sc.
Senior Research Officer—J. T. Jefferies, M.A., B.Sc. (overseas).
Senior Research Officer—J. V. Ramsay, B.Sc., Ph.D., D.I.C.
Research Officer—W. R. Blevin, M.Sc., Dip.Ed.
Research Officer—R. J. Bray, M.A., D.Phil.
Research Officer—W. A. Caw, B.Sc.
Research Officer—R. E. Loughhead, M.Sc.
Research Officer—J. V. McAllan, B.Sc.
Research Officer—J. Middlehurst, M.Sc.
Research Officer—A. F. Young, M.Sc.
Experimental Officer—Miss I. M. Beavis, B.Sc., Dip.Ed.
Experimental Officer—J. A. Birch, A.S.T.C.
Experimental Officer—W. J. Brown, A.S.T.C.
Experimental Officer—V. R. Burgess, A.S.T.C.
Experimental Officer—G. A. Creef, A.S.T.C.
Experimental Officer—P. M. G. Fead, B.E.E.
Experimental Officer—A. H. Flint, M.A.
Experimental Officer—T. P. Jones, M.Sc.
Experimental Officer—L. Kaagjarv, M.Sc.
Experimental Officer—Miss M. K. McCabe, M.Sc.
Experimental Officer—R. J. Tainsh, A.S.T.C.
Experimental Officer—K. A. B. Wright, B.Sc.

32. Division of Plant Industry.

(Head-quarters: Canberra, Australian Capital Territory.)

Administration—

Chief—O. H. Frankel, D.Sc., D.Agr., F.A.A., F.R.S.
Associate Chief—J. Griffiths Davies, B.Sc., Ph.D., D.Sc.
Assistant Chief—R. M. Moore, M.Sc.Agr. (overseas).
Technical Secretary—A. Shavitsky, B.Agr.Sc.
Assistant Technical Secretary—J. H. E. Mackay, B.Sc.Agr.
Divisional Engineer—G. L. Brown, B.Sc.(Eng.).

At Canberra, Australian Capital Territory—

Genetics, Cytology, and Structural Botany—

Chief of the Division—O. H. Frankel, D.Sc., D.Agr., F.A.A., F.R.S.
Principal Research Officer—C. Barnard, D.Sc.
Senior Research Fellow—J. B. Griffing, M.S., Ph.D.
Principal Research Officer—R. D. Brock, M.Agr.Sc., Ph.D.
Principal Research Officer—F. H. W. Morley, B.V.Sc., Ph.D., H.D.A.
Senior Research Officer—J. B. Langridge, M.Sc., Ph.D.
Senior Research Officer—D. C. Wark, M.Agr.Sc.
Research Officer—H. Daday, M.Sc.
Research Officer—C. I. Davern, M.Sc.Agr. (overseas).
Research Officer—D. L. Hayman, B.Ag.Sc.(Hons.), Ph.D.
Research Officer—B. D. H. Latter, B.Sc.Agr.(Hons.), Ph.D.
Research Officer—J. R. McWilliam, B.Sc.For. (Hons.), M.F., Ph.D.
Research Officer—D. M. Moore, B.Sc.(Hons.), Ph.D.
Research Officer—R. N. Oram, B.Ag.Sc.(Hons.) (at Wagga).
Experimental Officer—Miss A. M. Munday, B.Sc.
Experimental Officer—Miss V. E. Rogers, B.A. (Hons.) (at Deniliquin).

Plant Introduction—

Senior Principal Research Officer—W. Hartley, B.A., Dip.Ag.
Senior Research Officer—C. A. Neal-Smith, B.Ag.Sc.
Research Officer—R. J. Williams, M.Sc.
Experimental Officer—P. Broue, B.Sc.Agr.
Experimental Officer—Miss D. E. Johns, B.Sc.
Experimental Officer—Mrs. C. R. Slater, B.Sc.Agr.

Herbarium—

Senior Research Officer—Miss N. T. Burbidge, M.Sc.

Microbiology—

Principal Research Officer—A. V. Hill, M.Agr.Sc.
Senior Research Officer—I. A. M. Cruickshank, M.Sc.(Hons.).
Senior Research Officer—F. W. Hely, M.Sc.Agr., M.S.
Senior Research Officer—C. J. Shepherd, B.A., Ph.D.
Research Officer—F. J. Bergersen, M.Sc.(Hons.).
Research Officer—A. H. Gibson, B.Sc.Agr.(Hons.), Ph.D.
Research Officer—D. J. Goodchild, B.Sc.Agr. (Hons.), M.A.
Research Officer—Miss K. Helms, M.Sc., Ph.D.
Experimental Officer—J. Brockwell, D.D.A.
Experimental Officer—M. Mandryk, B.Sc.Agr. (Hons.).
Experimental Officer—Mrs. D. R. Perrin, M.Sc.

General Chemistry—

Principal Research Officer—C. H. Williams, M.Sc.
Senior Research Officer—D. J. Cosgrove, B.Sc. (Hons.), Ph.D.
Senior Research Officer—A. Steinbergs, Dip.Chem. Eng.
Research Officer—D. J. David, M.Sc.
Experimental Officer—J. R. Twine, Dip.Ind.Chem.

Plant Nutrition—

Senior Principal Research Officer—A. J. Anderson, D.Sc.(Agric.).
Senior Research Officer—J. F. Lonergan, B.Sc. (Hons.), Ph.D.
Senior Research Officer—K. D. McLachlan, B.Sc. Agr., B.Com.
Senior Research Officer—D. Spencer, B.Sc.(Hons.), Ph.D.
Research Officer—J. V. Possingham, B.Ag.Sc. (Hons.), Ph.D.
Experimental Officer—B. W. Norman, B.Sc.Agr.

Plant Biochemistry and Biophysics—

Senior Principal Research Officer—J. E. Falk, M.Sc., Ph.D.
Principal Research Officer—C. G. Greenham, M.Sc.
Senior Research Officer—N. K. Boardman, M.Sc., Ph.D.
Senior Research Officer—W. Bottomley, B.Sc. (Hons.), Ph.D.
Senior Research Officer — S. M. Bromfield, M.Agr.Sc., Ph.D.
Senior Research Officer—P. L. Goldacre, M.Sc., Ph.D.
Senior Research Officer—J. N. Phillips, M.Sc., Ph.D.
Senior Research Officer—S. W. Thorne, B.Sc. (Hons.).
Research Officer—C. A. Appleby, B.Sc.(Hons.), Ph.D.
Research Officer—P. A. Trudinger, B.Sc.(Hons.), Ph.D.
Research Officer—N. A. Walker, B.Sc.(Hons.), Ph.D.
Research Officer—P. R. Whitfield, B.Sc.(Hons.), Ph.D.
Experimental Officer—Mrs. M. B. Lowe, B.Sc. (Hons.).
Experimental Officer—P. I. Mortimer, M.Sc. (on leave).
Experimental Officer—R. J. Porra, B.Sc.(Hons.).

Plant Physiology—

Senior Principal Research Officer—R. F. Williams, D.Sc.
Principal Research Officer—L. A. T. Ballard, M.A., M.Agr.Sci., Ph.D.
Senior Research Officer—L. T. Evans, B.Sc., M.Agr.Sc., D.Phil.
Senior Research Officer—A. H. G. C. Rijven, B.Sc., Ph.D.
Research Officer—N. P. Kefford, M.Sc., Ph.D.
Research Officer—W. G. Slater, M.Sc., D.Phil.
Research Officer—J. A. Zwar, M.Ag.Sc. (overseas).
Experimental Officer—Miss C. A. Banbury, B.Sc.
Experimental Officer—Miss A. E. Grant Lipp, M.Sc.

Ecology—

Assistant Chief of the Division—R. M. Moore, M.Sc.Agr. (overseas).
Senior Research Officer—E. F. Biddiscombe, M.Sc.(Agric.).
Senior Research Officer—A. B. Costin, B.Sc.Agr. (Hons.).
Senior Research Officer—R. W. Jessup, M.Sc.
Senior Research Officer—E. C. Levi, M.Sc. (at Griffith) (on leave).
Senior Research Officer — C. W. E. Moore, M.Agr.Sc.
Senior Research Officer — G. Scurfield, B.Sc., Dip.Ed., Ph.D.
Research Officer—J. A. Carnahan, M.Sc.(Hons.), Ph.D.

Research Officer—P. W. Michael, B.Agr.Sc.(Hons.), Ph.D.
Experimental Officer—W. Straatmans, Dip.Ag., Dip.Trop.Agr.
Experimental Officer—J. D. Williams, D.D.A.
Experimental Officer—D. J. Wimbush, B.Sc. (at Island Bend).

Agricultural Physics—
Principal Research Officer—J. R. Philip, B.C.E.
Research Fellow—N. E. Rider, B.Sc.(Hons.).
Experimental Officer—A. J. Peck, B.Sc.(Hons.).

Agronomy—
Principal Research Officer—R. W. Prunster, B.Sc. (Agric.) (seconded to the Commonwealth Bank).
Principal Research Officer—W. M. Willoughby, B.Sc.Agr.
Senior Research Officer—W. D. Andrew, M.Agr. Sc.
Research Officer—G. W. Arnold, M.Sc.(Agric.).
Research Officer—J. Lipsett, B.Agr.Sc.(Hons.).
Research Officer—J. R. Simpson, M.Sc., Ph.D.

At Plant and Soils Laboratory, Brisbane, Queensland—
Associate Chief—J. Griffiths Davies, B.Sc.(Hons.), Ph.D., D.Sc.
Laboratory Secretary—A. G. A. Eyles, B.Sc.(Agric.).

Agrostology—
Principal Research Officer—T. B. Paltridge, B.Sc. (Hons.) (overseas with A.S.L.O., Washington).
Principal Research Officer — W. W. Bryan, M.Agr.Sc.
Principal Research Officer—N. H. Shaw, B.Agr.Sci. (Hons.).
Research Officer—L. A. Edye, B.Agr.Sc.(Hons.).
Research Officer—F. K. van der Kley, D.Ag.Sc.
Research Officer—L. t'Mannetje, Ir.
Research Officer—J. J. Yates, B.Sc. (Agric.) (Hons.).

Plant Nutrition and Physiology—
Senior Research Officer—C. S. Andrew, M.Agr.Sc. (Hons.).
Senior Research Officer — R. G. Coleman, B.Sc.(Agric.), Ph.D., D.I.C.
Research Officer—E. F. Henzell, B.Agr.Sc.(Hons.), D.Phil.

Plant Chemistry—
Research Officer—M. P. Hegarty, M.Sc., Ph.D.
Experimental Officer—R. D. Court, B.Sc.
Experimental Officer—Miss P. M. Thorne, B.Sc.

Ecology—
Senior Research Officer—J. E. Coaldrake, M.Sc.
Experimental Officer—W. F. Ridley, M.Sc.

Plant Breeding and Genetics—
Senior Principal Research Officer—E. M. Hutton, B.Agr.Sc., D.Sc.
Research Officer—A. J. Pritchard, B.Sc.(Hons.).
Experimental Officer—D. E. Byth, B.Agr.Sc.

Legume Bacteriology—
Senior Principal Research Officer—D. O. Norris, (Agric.).

Plant Introduction—
Research Officer—E. H. Kipps, B.Sc.

At Cooper Laboratory, Lawes, Queensland—
Pasture Evaluation and Animal Nutrition—
Research Officer—R. Milford, B.Agr.Sc.(Hons.).

At Regional Pastoral Laboratory, Armidale, New South Wales—
Pasture Investigations—
Principal Research Officer—R. Roe, B.Sc.(Agric.).
Senior Research Officer—E. J. Hilder, B.Sc.(Agric.).
Senior Research Officer—K. Spencer, B.Sc.Agr. (Hons.), M.S.
Research Officer—N. J. Barrow, M.Agr.Sc.
Research Officer—J. R. Freney, M.Sc.
Research Officer—J. L. Wheeler, B.Sc., Ph.D.
Experimental Officer—B. E. Mottershead, B.Sc.
Experimental Officer—J. A. Thompson, B.Sc.(For.).

At Regional Pastoral Laboratory, Deniliquin, New South Wales—
Officer-in-charge—L. F. Myers, M.Agr.Sc.
Library Assistant—Miss M. J. Johnston.

Pasture Investigations—
Senior Research Officer—O. B. Williams, M.Agr.Sc.
Research Officer—J. L. Davidson, M.Ag.Sc.
Research Officer—C. R. Kleinig, B.Ag.Sc.(Hons.).
Research Officer—R. H. Sedgley, M.Agr.Sc.
Experimental Officer—R. H. Crockford, A.R.M.T.C.
Experimental Officer—B. D. Millar, B.Sc.Agr.

At Regional Laboratory, Perth—
Pasture Investigations—
Principal Research Officer—R. C. Rossiter, D.Sc. (Agric.).
Senior Research Officer—P. G. Ozanne, B.Sc. (Agric.).
Research Officer—H. L. Davies, B.Sc.(Agr.) (Hons.).
Research Officer—A. W. Humphries, B.Sc.Agric. (Hons.).
Experimental Officer—D. J. Kirton, B.Sc.(Agric.).
Experimental Officer—T. C. Shaw, B.Sc.

Plant Introduction—
Senior Research Officer—E. T. Bailey, B.Sc.(Hons.).

At "Glen Lossie" Field Station, Kojonup, Western Australia—
Senior Research Officer—E. R. Watson, M.Sc. (Agric.).
Experimental Officer—P. Lapins, Dip.Agronom.

At Tasmanian Regional Laboratory, Hobart—
Fruit Investigations—
Principal Research Officer—D. Martin, D.Sc.
Research Officer—T. L. Lewis, M.Sc. (overseas).
Experimental Officer—J. Cerny, Dr.Tech.Sc.

At Applethorpe, Queensland—
Fruit Investigations—
Principal Research Officer—L. A. Thomas, M.Sc.

At University of Melbourne—
Soil Chemistry—
Principal Research Officer—L. H. P. Jones, B.Agr. Sc., Ph.D.

At University of Queensland, Brisbane—
Ecology—
Principal Research Officer—L. J. Webb, M.Sc., Ph.D.

At Tobacco Research Institute, Mareeba, Queensland—
Director—D. W. Goodall, Ph.D., D.Sc.
Senior Research Officer—W. J. Lovett, B.Agr.Sc.
Research Officer—P. J. Goodman, B.Sc.(Hons.), Ph.D.
Research Officer—J. van de Harst, Ing.Agr.
Research Officer—N. K. Matheson, M.Sc., Ph.D.

33. DIVISION OF RADIOPHYSICS.

(Head-quarters: University Grounds, Sydney.)

Administration—
Chief—E. G. Bowen, O.B.E., M.Sc., Ph.D., D.Sc., F.A.A.
Assistant Chief—J. L. Pawsey, M.Sc., Ph.D., F.A.A., F.R.S.
Technical Secretary—A. J. Higgs, B.Sc.(Hons.).
Principal Research Officer—L. L. McCready, B.Sc., B.E.

Cloud and Rain Physics—

Principal Research Officer—E. J. Smith, M.B.E., B.Sc.(Eng.)(Hons.).
Principal Research Officer—P. Squires, M.A.
Principal Research Officer—J. Warner, B.Sc., B.E.
Senior Research Officer—E. K. Bigg, M.Sc., Ph.D.
Senior Research Officer—G. A. Day.
Senior Research Officer—S. Twomey, M.Sc., Ph.D.
Senior Research Officer—A. A. Weiss, B.Sc.(Hons.), Ph.D.
Research Officer—E. E. Adderley, B.Sc.
Research Officer—N. H. Fletcher, B.Sc., M.A., Ph.D.
Research Officer—J. W. Telford, B.Sc.(Hons.).
Research Officer—J. A. Warburton, B.Sc.(Hons.).
Officer-in-charge, Experimental Flying—F. D. Bethwaite.
Experimental Officer—K. J. Heffernan.
Experimental Officer—J. W. Smith, B.Sc.

Radio Astronomy—

Senior Principal Research Officer—W. N. Christiansen, D.Sc., F.A.A.
Senior Principal Research Officer—B. Y. Mills, B.Sc., M.E., D.Sc. Eng., F.A.A.
Senior Principal Research Officer—J. H. Piddington, M.Sc., B.E., Ph.D.
Senior Principal Research Officer—J. P. Wild, M.A.
Principal Research Officer—F. J. Kerr, M.Sc., M.A.
Senior Research Officer—C. A. Shain, B.Sc.(Hons.).
Senior Research Officer—S. F. Smerd, B.Sc.(Hons.).
Research Officer—A. W. L. Carter, B.Sc.(Hons.).
Research Officer—C. S. Gumm, M.Sc., Ph.D.
Research Officer—E. R. Hill, M.Sc.
Research Officer—N. R. Labrum, B.Sc.(Hons.).
Research Officer—R. X. McGee, B.Sc.(Hons.).
Research Officer—R. F. Mullaly, M.Sc., Ph.D.
Research Officer—K. V. Sheridan, B.Sc., B.A.
Research Officer—O. B. Slee, B.Sc.
Research Officer—C. M. Wade, B.A., M.A., Ph.D.
Experimental Officer—E. Harting, A.S.T.C.
Experimental Officer—J. V. Hindman.
Experimental Officer—M. M. Komesaroff, B.Sc. (Hons.).
Experimental Officer—K. R. McAlister, A.S.T.C.
Experimental Officer—B. C. Milne, B.E.
Experimental Officer—J. D. Murray, B.Sc.(Eng.).
Experimental Officer—M. W. Willing, A.R.M.T.C.

Radio Navigation and Propagation—

Principal Research Officer—M. Beard, B.Sc., M.E.
Senior Research Officer—F. F. Gardner, B.Sc., B.E., Ph.D.
Senior Research Officer—D. E. Yabsley, B.Sc., B.E.
Experimental Officer—G. A. Chandler, B.E.
Experimental Officer—P. T. Hedges, A.S.T.C.

Semiconductors and Transistors—

Research Officer—R. D. Ryan, B.Sc.(Hons.), B.E.
Experimental Officer—B. M. Bartlett, B.Sc.
Experimental Officer—F. G. Tonking, A.S.T.C.

Test and Development—

Experimental Officer—T. E. Cousins, A.S.T.C.
Experimental Officer—G. A. Wells, A.S.T.C.

Officers Abroad—

Principal Research Officer—B. F. C. Cooper, B.Sc. (Hons.), B.E.
Principal Research Officer—H. C. Minnett, B.Sc., B.E.
Senior Research Officer—L. W. Davies, B.Sc.(Hons.), D.Phil.
Senior Research Officer—J. A. Roberts, M.Sc., Ph.D.
Research Officer—A. G. Little, B.Sc.
Research Officer—D. S. Mathewson, M.Sc.
Research Officer—B. J. Robinson, M.Sc., Ph.D.
Research Officer—J. S. Turner, M.Sc., Ph.D.

34. Soil Mechanics Section.

(Head-quarters: Coleman-parade, Syndal, Victoria.)

Principal Research Officer—G. D. Aitchison, M.E., Ph.D.
Research Officer—I. B. Donald, M.E.
Research Officer—R. H. G. Parry, M.E.Sc., Ph.D.
Experimental Officer—Miss M. G. Dettman, B.Ag.Sc., M.Sc.
Experimental Officer—P. O. Morris, B.C.E.
Experimental Officer—B. G. Richards, B.E.
Experimental Officer—C. J. Witherow, B.Sc.(Eng.).

35. Division of Soils.

(Head-quarters: Waite-road, Urrbrae, South Adelaide, South Australia.)

At Adelaide—

Administration—

Chief—J. K. Taylor, B.A., M.Sc., M.Sc.Agr.

Soil Survey and Pedology Section—

Senior Principal Research Officer—C. G. Stephens, D.Sc.
Principal Research Officer—G. Blackburn, B.Ag.Sc.
Principal Research Officer—K. H. Northcote, B.Ag.Sc.
Senior Research Officer—E. A. Jackson, B.Ag.Sc. (at Alice Springs).
Research Officer—G. G. Beckman, M.Sc.
Research Officer—C. B. Wells, M.Ag.Sc.

Soil Chemistry Section—

Senior Principal Research Officer—C. S. Piper, D.Sc.
Principal Research Officer—J. T. Hutton, B.Sc., A.S.A.S.M.
Principal Research Officer—A. C. Oertel, M.Sc.
Senior Research Officer—M. Raupach, M.Sc.
Senior Research Officer—H. C. T. Stace, M.Sc.
Senior Research Officer—B. M. Tucker, B.A., M.Sc.
Research Officer—K. G. Tiller, M.Sc. (on leave).
Experimental Officer—R. D. Bond, B.Tech.
Experimental Officer—A. R. P. Clarke, A.S.A.S.M.
Experimental Officer—J. B. Giles, B.Sc.
Experimental Officer—R. M. McKenzie, B.Tech.
Experimental Officer—M. P. C. deVries (l.i.).

Soil Physics Section—

Senior Principal Research Officer—T. J. Marshall, M.Ag.Sc., Ph.D.
Senior Research Officer—W. W. Emerson, B.A., Ph.D.
Senior Research Officer—E. L. Greacen, B.Sc.Agr., Ph.D.
Senior Research Officer—J. W. Holmes, M.Sc.
Research Officer—J. S. Colville, M.Sc.
Research Officer—C. G. Gurr, B.Sc.

Soil Microbiology Section—

Senior Principal Research Officer——R. J. Swaby, M.Sc., M.Ag.Sc., Ph.D.
Senior Research Officer—J. R. Harris, M.Sc.
Research Officer—G. D. Bowen, B.Sc.
Research Officer—J. N. Ladd, M.Sc. (on leave).
Research Officer—A. D. Rovira, B.Ag.Sc., Ph.D.
Experimental Officer—P. G. Brisbane, B.Sc.Agr.

Clay Mineralogy Section—

Senior Research Officer—K. Norrish, M.Sc., Ph.D.
Research Officer—E. W. Radoslovich, M.Sc., Ph.D.
Research Officer—J. A. Rausell Colom, D.Sc.
Experimental Officer—R. M. Taylor, B.Sc.

At Brisbane—

Soil Survey and Pedology Section—

Principal Research Officer—G. D. Hubble, B.Ag.Sc.
Research Officer—R. F. Isbell, M.Sc.
Research Officer—C. J. de Mooy (l.i.).
Experimental Officer—C. H. Thompson, Q.D.A.

Soil Physics Section—
Senior Research Officer—G. B. Stirk, B.Sc.
Experimental Officer—R. E. Prebble, B.Sc.

Soil Chemistry Section—
Principal Research Officer—A. E. Martin, D.Sc.
Senior Research Officer—R. S. Beckwith, B.Sc.
Experimental Officer—I. F. Fergus, B.Sc.
Experimental Officer—I. P. Little, B.Sc.Agr.
Experimental Officer—R. Reeve, Dip.Ind.Chem.

At Canberra—

Soil Survey and Pedology Section—
Senior Principal Research Officer—B. E. Butler, B.Sc. (Agric.).
Senior Research Officer—D. C. van Dijk, Ing.Agr., D.Sc.
Research Officer—J. A. Beattie, B.Sc.Agr. (on leave).
Research Officer—W. H. Litchfield, B.Sc.Agr. (seconded to Division of Land Research and Regional Survey).
Research Officer—J. Loveday, M.Ag.Sc., Ph.D. (at Griffith).
Research Officer—W. M. McArthur, B.Sc. (at (Armidale).
Research Officer—P. H. Walker, M.Sc.Agr. (at Sydney).

Soil Chemistry Section—
Experimental Officer—H. J. Beatty, Dip.Ind.Chem.
Experimental Officer—Miss M. P. Green, B.Sc.
Experimental Officer—R. J. Hunter, B.Sc. (on studentship leave).

Soil Physics Section—
Research Officer—D. S. McIntyre, M.Sc., Ph.D.
Experimental Officer—A. V. Blackmore, M.Sc. (on leave).

Soil Micropedology Section—
Principal Research Officer—R. Brewer, B.Sc.
Senior Research Officer—J. R. Sleeman, B.Ag.Sc.
Experimental Officer—B. F. Breese, B.Sc.

At Hobart—

Soil Survey and Pedology Section—
Principal Research Officer—K. D. Nicholls, B.Ag.Sc., B.Sc.
Research Officer—G. M. Dimmock, B.Sc.

Soil Chemistry Section—
Experimental Officer—A. M. Graley, B.Sc.
Experimental Officer—J. L. Honeysett, B.Sc.

At Perth—

Soil Survey and Pedology Section—
Senior Research Officer—M. J. Mulcahy, B.Sc.
Research Officer—H. M. Churchward, B.Sc.Agr.
Experimental Officer—E. Bettenay, B.Sc.(Agric.).

Soil Chemistry Section—
Experimental Officer—F. J. Hingston, B.Sc.
Experimental Officer—A. G. Turton, B.Sc.

36. DIVISION OF TRIBOPHYSICS.

(Head-quarters: University of Melbourne.)

Chief—W. Boas, M.Sc., D.Ing., F.A.A.
Principal Research Officer—L. M. Clarebrough, B.Met.E., M.Eng.Sc., Ph.D.
Principal Research Officer—M. E. Hargreaves, B.Met.E., Ph.D.
Principal Research Officer—J. K. Mackenzie, B.A.(Hons.), B.Sc., Ph.D.
Principal Research Officer—A. J. W. Moore, B.Sc., Ph.D.
Senior Research Officer—A. J. Davis, B.Eng.
Senior Research Officer—A. K. Head, B.A.(Hons.), B.Sc., Ph.D.
Senior Research Officer—D. Michell, B.E.E.
Senior Research Officer—J. F. Nicholas, B.A.(Hons.), B.Sc.
Senior Research Officer—G. J. Ogilvie, B.Met.E., M.Eng. Sc., Ph.D.
Senior Research Officer—J. V. Sanders, B.Sc.(Hons.), Ph.D.
Senior Research Officer—G. W. West, B.E.E., B.Sc.
Research Officer—J. Bagg, B.Sc., Ph.D.
Research Officer—Mrs. L. A. Bruce, B.Sc.(Hons.), Ph.D.
Research Officer—B. D. Cùming, M.Sc., Ph.D.
Research Officer—E. A. Faulkner, M.A.(Hons.).
Research Officer—D. F. Klemperer, B.Sc., Ph.D.
Research Officer—M. H. Loretto, B.Met.(Hons.).
Research Officer—H. G. Scott, B.A., Ph.D.
Research Officer—J. A. Spink, M.Sc.
Experimental Officer—E. D. Hondros, B.Sc.
Experimental Officer—H. K. A. Jaeger, A.R.A.C.I.
Experimental Officer—R. R. Johnston, B.Sc.
Experimental Officer—E. Lovegrove, A.R.M.T.C.
Experimental Officer—G. R. Perger, F.R.M.T.C.
Experimental Officer—R. G. Sherwood, A.R.M.T.C.
Experimental Officer—A. A. Thomson, A.R.M.T.C.
Experimental Officer—A. J. White, A.R.M.T.C.

37. UPPER ATMOSPHERE SECTION.

(Head-quarters: Harben Vale, Camden, New South Wales.)

Officer-in-charge—D. F. Martyn, D.Sc., Ph.D., F.A.A., F.R.S.
Senior Research Officer—G. R. A. Ellis, B.Sc., Ph.D.
Research Officer—R. A. Duncan, B.Sc.(Hons.).
Experimental Officer—D. G. Cartwright, B.Sc.(Hons.).
Experimental Officer—T. W. Davidson, M.Sc.

38. WHEAT RESEARCH UNIT.

(Head-quarters: 111 Pacific Highway, North Sydney, New South Wales.)

Officer-in-charge—E. E. Bond, A.R.M.T.C., F.R.A.C.I.
Leader of Unit—M. V. Tracey, M.A.

39. WILDLIFE SURVEY SECTION.

(Head-quarters: Canberra, Australian Capital Territory.)

Officer-in-charge—F. N. Ratcliffe, O.B.E., B.A.(Hons.).
Senior Principal Research Officer—R. Carrick, B.Sc. (Hons.), Ph.D.
Sectional Secretary—F. N. Robinson, B.A.
Principal Research Officer—H. J. Frith, B.Sc.Agr.
Principal Research Officer—M. E. Griffiths, D.Sc.
Senior Research Officer—J. H. Calaby, Dip.App.Chem.
Senior Research Officer—A. L. Dyce, B.Sc.Agr.(Hons.).
Research Officer—R. Mykytowycz, B.V.M., D.V.M.
Experimental Officer—J. M. MacLennan, M.A., B.Sc., Ph.D.
Experimental Officer—I. C. R. Rowley, B.Agr.Sc.
Scientific Librarian—Mrs. E. M. Wylie, B.Sc.

At Perth—
Principal Research Officer—D. L. Serventy, B.Sc. (Hons.), Ph.D.
Research Officer—E. H. M. Ealey, M.Sc.
Experimental Officer—S. J. J. Davies, B.A. (Hons.).

At Albury, New South Wales—
Senior Research Officer—K. Myers, B.Sc.(Hons.).
Research Officer—W. E. Poole, B.Sc.(Hons.).
Experimental Officer—J. S. Hayward, B.Sc.(Hons.).

At Armidale, New South Wales—
Senior Research Officer—B. V. Fennessy, B.Agr.Sc.
Experimental Officer—J. E. Bromell, B.Agr.Sc.

40. Wool Research Laboratories.

Division of Protein Chemistry, 343 *Royal Parade, Parkville, Victoria*—

Chief—F. G. Lennox, D.Sc.
Secretary—C. Garrow, B.Com., D.P.A., A.A.S.A.
Senior Principal Research Officer—W. G. Crewther, M.Sc.
Senior Principal Research Officer—H. Lindley, B.A., Ph.D.
Principal Research Officer—R. D. B. Fraser, Ph.D. (overseas).
Principal Research Officer—J. M. Gillespie, M.Sc.
Principal Research Officer—M. A. Jermyn, M.Sc., Ph.D.
Principal Research Officer—S. J. Leach, B.Sc.Tech., Ph.D.
Principal Research Officer—T. A. Pressley, B.Sc.
Principal Research Officer—J. M. Swan, B.Sc., Ph.D.
Principal Research Officer—E. F. Woods, M.Sc., A.R.M.T.C.
Senior Research Officer—B. S. Harrap, M.Sc., Ph.D. (overseas).
Senior Research Officer—I. J. O'Donnell, M.Sc.
Senior Research Officer—G. E. Rogers, M.Sc., Ph.D.
Senior Research Officer—W. E. Savige, M.Sc., Ph.D.
Senior Research Officer—E. O. P. Thompson, M.Sc., Dip.Ed., Ph.D.
Research Officer—J. A. McLaren, M.Sc., Ph.D.
Research Officer—T. P. MacRae, M.Sc.
Research Officer—B. Milligan, Ph.D.
Research Officer—C. M. Roxburgh, Ph.D.
Research Officer—P. H. Springell, M.A., Ph.D.
Research Officer—G. Youatt, B.Sc., Ph.D.
Senior Experimental Officer—J. P. E. Human, M.Sc., Ph.D.
Experimental Officer—L. M. Dowling, B.Sc.
Experimental Officer—A. B. McQuade, B.Sc.
Experimental Officer—R. J. Rowlands, B.Sc.
Experimental Officer—I. W. Stapleton, Dip.Chem.
Experimental Officer—K. I. Wood, A.R.M.T.C.

Division of Textile Physics, 338 *Blaxland-road, Ryde, New South Wales*—

Chief—V. D. Burgmann, B.Sc., B.E.
Administrative Officer—J. I. Platt, B.Sc.(Econ.).
Principal Research Officer—J. G. Downes, B.Sc.
Principal Research Officer—M. Feughelman, B.Sc., A.S.T.C.
Principal Research Officer—N. F. Roberts, M.Sc.
Senior Research Officer—H. W. Holdaway, B.Sc., B.E.
Senior Research Officer—Mrs. K. R. Makinson, B.A.
Research Officer—M. W. Andrews, B.Sc., Ph.D.
Research Officer—K. Baird, M.Sc., Ph.D.
Research Officer—E. G. Bendit, B.Sc.(Eng.), M.Sc.
Research Officer—E. F. Denby, B.Sc., Ph.D., D.I.C.
Research Officer—A. R. Haly, M.Sc.
Research Officer—J. F. P. James, M.Sc.
Research Officer—D. T. Liddy, B.Sc.
Research Officer—H. W. M. Lunney, B.Sc., B.E.
Research Officer—P. Nordon, B.Sc., A.S.T.C., Ph.D.
Research Officer—B. J. Rigby, M.Sc.
Research Officer—I. M. Stuart, M.Sc.
Research Officer—I. C. Watt, M.Sc., Ph.D.
Experimental Officer—J. E. Algie, B.E., A.S.T.C.
Experimental Officer—Miss J. C. Griffith, M.Sc., A.S.T.C.
Experimental Officer—R. H. Kennett, B.Sc., A.S.T.C.
Experimental Officer—B. H. Mackay, B.Sc., A.S.T.C.
Experimental Officer—G. B. McMahon, B.Sc.
Experimental Officer—T. W. Mitchell, A.S.T.C.
Experimental Officer—D. Ross, A.S.T.C.
Experimental Officer—A. Sebestyen, Dip.M.E., D.Sc.
Experimental Officer—G. L. Scott, A.S.T.C.
Librarian—Miss H. G. Barr, B.A.(Hons.).

Division of Textile Industry, Geelong, Victoria—

Chief—M. Lipson, B.Sc., Ph.D.
Technical Secretary—T. Topham, A.T.I.
Principal Research Officer—G. W. Walls, B.Sc.
Senior Research Officer—J. H. Bradbury, M.Sc., Ph.D.
Senior Research Officer—A. J. Farnworth, M.B.E., M.Sc., Ph.D., A.G.Inst.Tech.
Senior Research Officer—D. S. Taylor, B.A., B.Sc., Ph.D.
Senior Research Officer—G. F. Wood, B.Sc., Ph.D.
Research Officer—C. A. Anderson, B.Sc. (overseas).
Research Officer—J. Delmenico, B.Sc. (overseas).
Research Officer—D. E. Henshaw, B.Sc.
Research Officer—J. R. McPhee, B.Sc., Ph.D.
Research Officer—W. V. Morgan, B.Sc.
Research Officer—G. H. Tauber, Dipl.Chem., Ph.D.
Research Officer—V. A. Williams, B.Sc., Ph.D.
Experimental Officer—M. A. Higgins, A.G.Inst.Tech.
Experimental Officer—B. O. Lavery.
Experimental Officer—A. R. W. Lee, B.Sc., Dip.Ed.
Experimental Officer—J. D. Leeder, A.G.Inst.Tech.
Experimental Officer—D. C. Shaw, B.Sc.
Experimental Officer—Mrs. M. Swingler, B.Sc.
Experimental Officer—G. C. West, A.G.Inst.Tech.

41. Unattached Officers.

Senior Principal Research Officer—J. E. Cummins, M.Sc. (seconded to International Atomic Energy Agency).
Senior Principal Research Officer—G. H. Munro, D.Sc. (seconded to Electrical Engineering Department, University of Sydney).
Principal Research Officer—J. C. M. Fornachon, B.Agr.Sc., M.Sc. (seconded to Australian Wine Research Institute).
Research Officer—K. R. Lynn, B.Sc.(Hons.) (on leave).
Research Officer—B. C. Rankine, M.Sc. (seconded to Australian Wine Research Institute).
Experimental Officer—L. Heisler, B.Sc. (seconded to Electrical Engineering Department, University of Sydney).
Experimental Officer—J. N. Stephens, M.A. (on leave).
Experimental Officer—W. R. Stern, B.Agr.Sc., M.Sc. (on leave).
Experimental Officer—P. R. Strutt, B.Sc. (on leave).

XXXIV. PUBLISHED PAPERS.

The following papers have been published during the year. Letters Patent granted to the Organization during the year are also included.

1. Animal Genetics Section.

Claringbold, P., *and* Sobey, W. R. (1958).—Studies in anaphylaxis. III. Re-examination of scores for anaphylaxis using four inbred lines of mice. *Aust. J. Biol. Sci.* 11: 434-41.

Dun, R. B. (1958).—The influence of selection and plane of nutrition on the components of fleece weight in Merino sheep. *Aust. J. Agric. Res.* 9 : 802-18.

Fraser, A. S. (1959).—Simulation of genetic systems by automatic digital computers. 5. Linkage, dominance and epistasis. Proc. Int. Symp. on Biometrical Genetics.

Fraser, A. S., *and* Hall, R. (1958).—Effects of X-irradiation on foetal development. *Aust. J. Biol. Sci.* 11: 425-33.

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Stephenson, K. M. (1959).—Wool follicle development in the New Zealand Romney and N-type sheep. IV. Pre-natal growth and changes in body proportions. *Aust. J. Agric. Res.* 10 : 433-52.

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2. DIVISION OF ANIMAL HEALTH AND PRODUCTION.

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Alexander, G. (1958).—Heat production of new-born lambs in relation to type of birth-coat. *Proc. Aust. Soc. Anim. Prod.* 2 : 10-14.

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[*] Department of Agriculture, Western Australia.
[†] University of New England, New South Wales.
[‡] University of Adelaide.

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3. DIVISION OF BIOCHEMISTRY AND GENERAL NUTRITION.

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XXXV. FINANCE.

1. Expenditure.

Expenditure from 1st July, 1958, to 30th June, 1959, is as follows:—

	£	£	£
(*a*) Salaries and contingencies			310,576*
(*b*) Investigations—			
(i) Animal Health and Production		776,186	
Less contributions from—			
Wool Research Trust Fund Trust Account	351,141		
Australian Dairy Produce Board	2,015		
United Graziers' Association of Queensland	233		
Ian McMaster Bequest	1,732		
Alexander Fraser Memorial Fund	300		
Wm. McIlrath Fellowship	2,250		
Burdekin Bequest (Drought Feeding)	737		
The Population Council Inc.	1,873		
Special Revenue Funds—			
"Belmont" Field Station	9,566		
		369,787	
			406,399
(ii) Biochemistry and General Nutrition		133,552	
Less contributions from—			
Wool Research Trust Fund Trust Account	47,048		
Various Contributors	500		
		47,548	
			86,004
(iii) Plant Industry		831,237	
Less contributions from—			
Wool Research Trust Fund Trust Account	138,081		
River Murray Commission and Snowy Mountains Hydro-Electric Authority	3,750		
Brown Rot Trust Fund	2,056		
Wheat Research Trust Account	4,658		
		148,545	
			682,692
(iv) Entomology			270,991
Less contributions from—			
Department of Primary Industry	11,319		
United Graziers Association and Australian Meat Board	2,778		
Wheat Research Trust Account	200		
		14,297	
			256,694
(v) Irrigation—			
(*a*) Irrigation Research Station, Griffith		79,424	
Less contributions from—			
N.S.W. Water Conservation and Irrigation Commission	2,000		
Special Revenue Fund—			
Griffith Research Station	8,900		
		10,900	
			68,524
(*b*) Commonwealth Research Station, Merbein		75,056	
Less contributions from—			
Dried Fruits Control Board	1,116		
		1,116	
			73,970
			142,494
(vi) Soils Mechanics		42,910	
Less contributions from—			
Department of Supply	16,440		
		16,440	
			26,470
(vii) Soils			232,615
(viii) Food Preservation and Transport		263,480	
Less contributions from—			
N.S.W. Department of Agriculture	2,076		
Metropolitan Meat Industry Board	512		
Queensland Meat Industry Board	1,378		
Australian Meat Board	627		
Australian Egg Board	793		
Department of Primary Industry	2,139		
Department of the Army	6,770		
Various Contributors	2,002		
Apple and Pear Board	614		
		16,911	
			246,569
(ix) Forest Products		336,868	
Less contributions from—			
Australian Paper Manufacturers Ltd. Associated Pulp and Paper Mills Ltd. Australian Newsprint Mills New Zealand Forest Products Ltd.	6,048		
Department of Territories	3,441		
General Donations	4,991		
Pole Strength Research Account	7,499		
Australian Plywood Board	9,319		
		31,298	
			305,570

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* The main items of expenditure under this heading are salaries of the administrative staff at the Organization's Head Office; salaries and expenses of officers at the Liaison Offices in London and Washington; staff and upkeep of State Committees; travelling expenses of Head Office staff; and general office expenditure.

	£	£	£
(x) Mining and Metallurgy	..	52,350	
Less contributions from—			
Australasian Institute of Mining and Metallurgy	2,036		
Consolidated Zinc Pty. Ltd.	998		
General Donations	3,664		
		6,698	
			45,652
(xi) Radio Research	..	54,574	
Less contributions from—			
Postmaster-General's Department	15,788		
Australian Broadcasting Control Board and Overseas Telecommunications Commission	4,000		
		19,788	
			34,786
(xii) Research Services	..	321,393	
Less contributions from—			
Wool Research Trust Fund Trust Account	12,374		
Wheat Research Trust Fund	5,330		
		17,704	
			303,689
(xiii) Chemical Research	..	678,571	
Less contributions from—			
Cement and Concrete Association of Australia	812		
Mt. Morgan Ltd., Mt. Lyell Mining and Railway Co. Ltd., and Mt. Isa and Peko N.L.	1,566		
Various Contributors	825		
Rio Tinto Pty. Ltd.	1,647		
Smith, Kline, and French Laboratories (U.S.A.)	3,504		
Commonwealth Aluminium Corporation	540		
Chamber of Mines (W.A.) Inc.	343		
The Population Council Inc.	433		
Zircon Rutile Pty. Ltd., Australian Titan Products Pty. Ltd., Western Titanium N.L., and Associated Minerals Consolidated	3,412		
		13,082	
			665,489
(xiv) Fisheries and Oceanography	..	198,144	
Less contributions from—			
Fisheries Development Trust Fund	6,139		
Department of the Navy	4,617		
Department of Primary Industry	1,214		
		11,970	
			186,174
(xv) Mathematical Statistics	..	..	68,113
(xvi) National Standards Laboratory	..	657,310	
Less contributions from—			
Department of Supply	1,294		
General Donations	393		
Machinability Donations	886		
		2,573	
			654,737
(xvii) Tribophysics	..	..	107,309
Less contributions from—			
Broken Hill Associated Smelters Pty. Ltd.	7,162		
H. C. Sleigh Ltd.	455		
General Donations	620		
		8,237	
			99,072
(xviii) Building Research	..	157,049	
Less contributions from—			
Associated Fibrous Plaster Manufacturers of Australia	2,639		
Paint Manufacturers Association	2,388		
State Electricity Commission	884		
General Donations	61		
		5,972	
			151,077
(xix) Fodder Conservation	..	..	32,598
(xx) Radiophysics	..	403,453	
Less contributions from—			
Snowy Mountains Hydro-Electric Authority	2,767		
Department of Civil Aviation	9,015		
		11,782	
			391,671
(xxi) Metallurgical Research	..	..	11,377
(xxii) Tobacco Research	..	37,314	
Less contributions from—			
Tobacco Research Trust	35,044		
Special Revenue Fund— Tobacco Research Station, Mareeba	2,270		
		37,314	
(xxiii) Meteorological Physics	..	..	91,684
(xxiv) Dairy Research	..	74,449	
Less contributions from—			
James Bell Machinery Pty. Ltd.	379		
Australian Dairy Produce Board	3,352		
		3,731	
			70,718
(xxv) Wool Research	..	446,402	
Less contributions from—			
Wool Research Trust Fund Trust Account	422,141		
Wool Buying and Selling Account	12,205		
G. C. Firth	92		
Patons and Baldwins Ltd.	19		
		434,457	
			11,945

	£	£	£
(xxvi) Fuel Research		203,276	
Less contributions from—			
General Donations	1,090		
		1,090	
			202,186
(xxvii) Wildlife Survey		125,962	
Less contributions from—			
Wool Research Trust Fund Trust Account	52,349		
Australian Newsprint Mills Pty. Ltd.	1,142		
Northern Territory Administration	466		
		53,957	
			72,005
(xxviii) Land Research and Regional Survey		202,226	
Less contributions from—			
Department of National Development	1,817		
Department of Territories	22,273		
Australian Meat Board	705		
Northern Territory Administration	13,167		
		37,962	
			164,264
(xxix) Genetics Investigations		70,010	
Less contributions from—			
Wool Research Trust Fund Trust Account	33,064		
Rural Bank and George Aitken Pastoral Research Trust	408		
		33,472	
			36,538
(xxx) Miscellaneous—			
(*a*) Biophysical Research		2,244	
(*b*) Patent Fees		5,057	
(*c*) Extra-mural Investigations		35,853	
(*d*) Furlough and Compensation		18,778	
(*e*) Wheat Research		6,818	
(*f*) Various		11,901	
		80,651	
Less contributions from—			
Science and Industry Endowment Fund	1,767		
Wheat Research Trust Account	6,818		
		8,585	
			72,066
Total of Item (*b*)—Investigations			5,751,348
(*c*) Grants—			
(i) Research Associations—			
Leather Research Association	5,891		
Bread Research Institute	11,017		
Wine Research Institute	3,500		
Tobacco Research Trust	10,500		
Coal Association (Research) Ltd.	10,000		
		40,908	
(ii) Overseas Research Studentships		70,428	
		111,336	
Less contributions from—			
Wool Research Trust Fund Trust Account	2,346		
Science and Industry Endowment Fund	108		
		2,454	
			108,882
Total Salaries and Contingencies, Investigations, and Grants			6,170,806
Less receipts from sales of equipment, publications, &c., and revenue earned by Divisions and Sections, details of which are shown in Section 4			85,505
			6,085,301

2. CONTRIBUTIONS.

This Section shows receipts and disbursements during the year 1958-59 of the funds provided by contributors and recorded in a special account entitled "Specific Research Trust Fund". It includes transactions financed from wool funds, details of which appear in Section 3 of this Chapter. Of the total expenditure of £1,677,729 recorded in this Fund, £1,367,671 refers to normal research activities and £310,058 to capital works. The following table summarizes the sources of these funds and the activities on which they were expended.

Source of Funds.	Activity.		Total.
	Investigations.	Capital Works.	
Wool Research Trust Fund Trust Account	1,058,545	264,031	1,322,576
Contributions (other than Wool)	309,126	46,027	355,153
	1,367,671	310,058	1,677,729

The details are as follows:—

	Receipts 1958-59 and balances brought forward from 1957-58.	Expenditure 1958-59.
	£	£
Wool Research Trust Fund Trust Account. (Details are shown in Section 3)	1,355,172	1,322,576
Australian Dairy Produce Board (Mastitis Investigations)	2,080	2,015
W. McIlrath Research Fellowship Fund (Expenses of Fellowship—Animal Husbandry)	2,250	2,250
Australian Meat Board (Parasitological Studies of Cattle)	6	..
Australian Dairy Produce Board (Parasitological Studies of Cattle)	3	..
Alexander Fraser Memorial Fund (Animal Health and Production Investigations)	422	300
Estate of the late Captain Ian McMaster (Animal Health and Production Investigations)	2,533	1,732
Burdekin Bequest (Drought Feeding Investigations)	2,961	737

	Receipts 1958-59 and balances brought forward from 1957-58.	Expenditure 1958-59.
	£	£
Special Revenue Fund—"Belmont" Field Station, Rockhampton (Animal Health and Production Investigations)	16,003	9,566
Special Reserve Fund—National Field Station, "Gilruth Plains", Cunnamulla (Animal Health and Production Investigations)	3,819	..
Special Revenue Fund—Burdekin Bequest (Animal Health and Production Investigations)	2,605	..
United Graziers' Association of Queensland (Animal Health and Production Investigations) ..	1,500	233
J. R. Allen, Esquire, Mortlake, Victoria (Animal Health and Production Investigations)	200	..
Trust Fund Brown Rot Investigations—Brown Rot Survey (Plant Industry)	2,296	2,056
General Donations (Plant Industry)	50	..
Western Australian Golf Association (Plant Industry Investigations) ..	50	..
River Murray Commission and Snowy Mountains Hydro-electric Authority—Alpine Ecology Investigations (Plant Industry)	3,281	3,750*
Australian Tobacco Research Trust (Tobacco Investigations) ..	35,044	35,044
Special Revenue Fund—Research Station, Mareeba (Tobacco Research Investigations)	4,931	2,270
Special Revenue Fund—Grazing Trials, Samford Farm (Plant Industry Investigations)	225	..
United Graziers' Association of Queensland and Australian Meat Board—Cattle Tick Investigations (Entomology)	3,750	2,778
Department of Primary Industry (Fruit Fly Investigations—Entomology)	11,878	11,319
U.S.A. Department of Health, Education and Welfare—Multiplication of an Insect Polyhedron Virus (Entomology)	1,560	..
Australian Dairy Produce Board—Black Beetle Investigations (Entomology)	1,000	..
Department of Supply (Soil Mechanics Investigations) ..	28,490	16,440
General Donations (Soil Mechanics Investigations)	16	..
Department of Works and the States' Roads Boards—Subgrade Moisture Investigation (Soil Mechanics Investigations)	3,600	..
N.S.W. Water Conservation and Irrigation Commission (Maintenance of Griffith Research Station) ..	2,000	2,000
Packing Companies and Co-operative Fruit Sales Ltd. (Dried Vine Fruits Investigations—Merbein) ..	14	..
Dried Fruits Control Board (Dried Fruits Investigations)	1,623	1,116
Nyah-Woorinen Dried Fruits Inquiry Committee (Dried Fruits Investigations)	525	..
Special Revenue Fund—Research Station, Griffith (Citricultural Investigations)	18,647	8,900
Australian Meat Board (Meat Investigations)	751	627
Metropolitan Meat Industry Board of New South Wales (Meat Investigations)	523	512
Queensland Meat Industry Board (Meat Investigations)	1,379	1,378
Department of the Army (Mutton Dehydration Investigations) ..	6,958	6,770
N.S.W. Department of Agriculture (Food Investigations)	1,099	1,090
Department of Primary Industry (Fruit Fly Investigations—Food Investigations)	2,494	2,113
Apple and Pear Board (Food Investigations)	616	614
Various Contributors (Division of Food Preservation and Transport)	7,920	2,002

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* Expenditure on this work in excess of receipts will be recovered in 1959–60.

	Receipts 1958-59 and balances brought forward from 1957-58.	Expenditure 1958-59.
	£	£
Australian Egg Board (Division of Food Preservation and Transport—Egg Investigations)	865	793
Department of Primary Industry—Spray Residue Investigations (Food Preservation and Transport) ..	100	26
N.S.W. Department of Agriculture—Quick Freezing of Fruit and Vegetables (Division of Food Preservation and Transport) ..	1,086	986
Paper Companies and New Zealand Forest Products (Paper Pulp Investigations)	8,071	6,048
Sundry Contributors (Forest Products Investigations)	8,576	4,991
General Donations—Pole Strength Research (Forest Products) ..	9,896	7,499
Department of Territories (Development of Pulp and Paper Industry in New Guinea)	3,562	3,441
Australian Plywood Board—Veneer, Gluing, and Plywood Research (Forest Products)	9,172	9,319*
Australasian Institute of Mining and Metallurgy (Mineragraphic Investigations)	2,036	2,036
Consolidated Zinc Pty. Ltd. (Ore-dressing Investigations)	998	998
General Donations (Ore-dressing Investigations)	6,481	3,664
State Electricity Commission of Victoria (Mineragraphic Investigations—Geological Consultations) ..	1,370	..
Miscellaneous Contributors (Mineragraphic Investigations)	116	..
Postmaster-General's Department (Radio Research)	15,788	15,788
Australian Broadcasting Control Board and Overseas Telecommunications Commission—Radio Research at Universities of Queensland and Adelaide	4,000	4,000
Miscellaneous Contributors (Chemical Research Laboratories)	8,703	..
State Electricity Commission, Gas and Fuel Corporation, and Australian Paper Manufacturers Ltd.—Clinkering of Brown Coal Ash (Chemical Research Laboratories)	4,484	825
Zircon Rutile Pty. Ltd., Australian Titan Products Pty. Ltd., Western Titanium N.L., and Associated Minerals Consolidated—Production of Rutile from Ilmenite (Chemical Research)	3,412	3,412
Commonwealth Aluminium Corporation—C.Z. Project (Chemical Research)	540	540
Western Australia Chamber of Mines (Inc.)—Cyanidation of Gold (Chemical Research)	2,000	343
Mt. Morgan Ltd., Mt. Lyell Mining and Railway Co. Ltd., Mt. Isa Ltd., and Peko N.L.—Electrowinning of Copper (Chemical Research) ..	1,566	1,566
Cement and Concrete Association of Australia (Cement Investigations—Chemical Research)	4,637	812
Rio Tinto Pty. Ltd.—Water Evaporation Control (Chemical Research)	1,647	1,647
Smith, Kline, and French Laboratories, U.S.A.—Phytological Survey and Drug Plant Collection (Chemical Research)	9,367	3,504
N.S.W. Government (Fisheries Investigations)	252	..
Department of the Navy (Marine Fouling Investigations—Division of Fisheries and Oceanography) ..	4,655	4,617
Department of Primary Industry—Pearl Shell Survey (Division of Fisheries and Oceanography) ..	1,214	1,214
Fisheries Development Trust Fund—Barracouta Investigations (Division of Fisheries and Oceanography) ..	12,247	6,139
Department of Supply—Examination of Gauges (Metrology)	3,126	1,293

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* Expenditure on this work in excess of receipts will be recovered in 1959–60.

	Receipts 1958-59 and balances brought forward from 1957-58.		Expenditure 1958-59.
	£		£
General Donations (Division of Physics)	361	..	361
Miscellaneous Contributors (Mathematical Instruments Section) ..	126	..	..
General Donations (Metrology) ..	110	..	..
Machinability Donations Account (Metrology)	1,000	..	886
General Donations (Electrotechnology)	71	..	33
General Donations (Tribophysics) ..	825	..	620
Broken Hill Associated Smelters Pty. Ltd.—Co-operative Research (Tribophysics)	7,162	..	7,162
H. C. Sleigh Ltd.—Research on Solid Lubricants (Tribophysics) ..	1,500	..	455
State Electricity Commission—Design and Use of Briquette Space Heaters (Building Research)	1,412	..	884
Associated Fibrous Plaster Manufacturers of Australia—Fibrous Plaster Research (Division of Building Research)	2,803	..	2,639
Paint Manufacturers' Association—Paint Research on Plaster Surfaces (Division of Building Research) ..	2,523	..	2,388
General Donations (Division of Building Research)	2,393	..	60
Cement and Concrete Association of Australia (Building Research) ..	3,500	..	..
Australian Wool Board (Biochemistry and General Nutrition Investigations —Sheep Research)	778	..	..
Various Contributors (Biochemistry and General Nutrition)	500	..	500
Radio Astronomy Trust (Division of Radiophysics)	16,027	..	16,027
Snowy Mountains Hydro-electric Authority—Cloud Seeding Investigations (Division of Radiophysics) ..	3,028	..	2,767
Department of Civil Aviation—Radio Navigational Aids (Division of Radiophysics)	15,000	..	9,015
Various Contributors—Rain and Cloud Physics Research (Radiophysics)	8,000	..	..
Committee for Dried Fruit Marketing (Division of Meteorological Physics)	12	..	..
Australian Dairy Produce Board—(Cheese-making Project—Dairy Research)	474	..	458
Australian Dairy Produce Board—Studentship in Dairy Chemistry (Dairy Research)	1,000	..	892
Australian Dairy Produce Board—Mechanization of Cheese Manufacture (Dairy Research)	2,500	..	2,002
James Bell Machinery Pty. Ltd.—Mechanization of Cheese Manufacture (Dairy Research)	394	..	379
Wool Buying and Selling Account (Wool Research)	17,045	..	12,205
Donations for Worsted Processing Research (Wool Research) ..	169	..	..
Shell (Chemical) Aust. Pty. Ltd.—Mothproofing Investigations (Wool Research)	27	..	..
Patons and Baldwins Ltd.—Solvent Degreasing (Wool Research) ..	20	..	20
G. C. Firth—Solvent Degreasing Trial (Wool Research)	..	..	92*
Associated Woollen Worsted Textile Manufacturers of Australia (Wool Research)	2,032	..	..
Various Contributors (International Wool Research Conference) ..	50	..	..
General Donations (Wool Research)	31	..	..
Princeton Institute, U.S.A.—Princeton Wool Project (Wool Research) ..	2	..	..
General Donations (Coal Investigations)	3,489	..	1,090
Petfoods Ltd.—Food for Budgerigars (Wildlife Investigations) ..	100	..	..
N.T. Administration—Goose Damage to Rice Crops (Wildlife Investigations)	535	..	466
I.C.I.A.N.Z. Ltd.—Duck Banding Investigations (Wildlife Section) ..	54	..	..
Australian Newsprint Mills Pty. Ltd. —Effect of Native Fauna on Eucalypt Regeneration (Wildlife Investigations)	1,500	..	1,142
Department of National Development —Kimberley Research Station (Land Research and Regional Survey) ..	2,053	..	1,817
Department of Territories—Resources Survey in Papua and New Guinea (Land Research and Regional Survey)	22,830	..	22,273
Australian Meat Board—Pasture Development in Central Australia (Land Research and Regional Survey)	735	..	704
Northern Territory Administration—Rice Research (Land Research and Regional Survey)	21,096	..	13,167
General Donations (Genetics Investigations)	640	..	408
Sundry Contributors (Commonwealth Scientific and Industrial Research Organization—Publications) ..	29	..	..
Science and Industry Endowment Fund	1,874	..	1,874
Wheat Research Trust Account ..	52,520	..	47,007*
The Population Council Inc.—Studies on Induced Infertility	10,659	..	2,247
Commonwealth Bank (Genetics Investigations)	3	..	..
	1,869,232	..	1,677,729

3. Wool Research Trust Fund Trust Account.

Details of transactions during 1958-59 are as follows:—

	£
Balance brought forward from 1957-58	21,172
Received from Department of Primary Industry during 1958-59	1,334,000
	1,355,172

Expenditure 1958-59.

	£	£	£
Investigations.			
Division of Animal Health and Production—			
Sheep Biology Laboratory, Prospect	195,406		
McMaster Laboratory ..	29,550		
Divisional Field Stations ..	14,445		
Regional Laboratory and "Chiswick" Field Station, Armidale	68,575		
Tooradin	6,017		
National Field Station, "Gilruth Plains"	37,148		
		351,141	
Division of Plant Industry—			
Head-quarters, Canberra ..	43,573		
Regional Pastoral Laboratory and Falkiner Memorial Field Station, Deniliquin ..	17,543		
Field Investigations, Armidale ..	40.804		
Western Australian Investigations	36,162		
		138,081	
Research Services—			
Agricultural Research Liaison Section	11,814		
Wool Publications	560		
		12,374	
Division of Biochemistry and General Nutrition—			
Nutrition Laboratory, Adelaide	17,217		
Field Studies at Glenthorne, Robe, and Brecon	29,831		
		47,048	
Wool Textile Research—			
Protein Chemistry, Melbourne	126,119		
Textile Physics, Sydney ..	109,683		
Textile Industry, Geelong ..	151,766		
Chemical Research Laboratories	34,573		
		422,141	

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* Expenditure on this work in excess of receipts will be recovered in 1959–60.

* The actual expenditure chargeable to the Wheat Research Trust Account during 1958–59 is £47,370. The adjustment of £363 will be made in 1959–60.

	£	£	£
Wildlife Survey Section—			
Wildlife Investigations ..	52,349		
		52,349	
Animal Genetics Section—			
Animal Genetics Investigations	33,064		
		33,064	
Overseas Studentships—			
Biological Research	1,278		
Wool Textile Research ..	1,069		
		2,347	
Total Investigations ..			1,058,545
Capital Works.			
C.S.I.R.O. Expenditure—			
Biological Research—			
Division of Animal Health and Production—			
Laboratory Equipment ..	7,433		
Division of Plant Industry—			
Laboratory Equipment ..	4,494		
		11,927	
Wool Textile Research—			
Wool Research Laboratories—			
Laboratory Equipment ..	30,367		
Textile Finishing and Testing Equipment incl. Sliver Converter	64,882		
Solvent Degreasing Project	875		
		96,124	
Department of Works Expenditure—			
Biological Research	127,716		
Wool Textile Research ..	28,264		
		155,980	
Total Capital Works ..	..	..	264,031
Total Expenditure ..	..	..	1,322,576
Balance carried forward to 1959-60	..	..	32,596
			1,355,172

During the year £58,446 was received from sales of sheep, wool, and other produce from C.S.I.R.O. Field Stations and Laboratories financed from wool funds. This amount was paid to the Department of Primary Industry for credit to the Wool Research Trust Fund Trust Account.

4. Miscellaneous Receipts.

During 1958-59 miscellaneous receipts amounted to £85,505. Details of the receipts are as follows:—

	£	£
Sale of publications	5,551	
Sale of equipment purchased in former years, and other receipts	22,100	
Sale of produce by Field Stations and Laboratories	56,175	
Royalties from patents	1,679	
		85,505

The receipts from the sale of produce represent revenue earned by Divisions and Sections apart from the Special Revenue included in Section 2.

The amount of £85,505 was credited to the Trust Fund—Science and Industry Account and consequently reduced the requirements from the Treasury by that amount (*see* Section 1).

5. Works Projects (Under Control of C.S.I.R.O.).

Treasury expenditure on works projects financed from funds made available directly to C.S.I.R.O. is as follows:—

	£	£	£
Plant Industry—			
Ginninderra Experiment Station ..	1,544		
Canberra Laboratories	1,824		
Development of the Phytotron ..	47,508		
		50,876	
Entomology—			
Cattle Tick Investigations at Ingham and Townsville	205		
		205	
Food Preservation—			
Cannon Hill Laboratory	2,474		
		2,474	
Fisheries and Oceanography—			
Cronulla Laboratory	862		
		862	
Meteorological Physics—			
Lysimeter Project, Aspendale ..	2,058		
		2,058	
Fuel Research—			
Coal Research Laboratory	992		
		992	
Radiophysics—			
Giant Radio Telescope	18,220		
		18,220	
Treasury Expenditure			75,687

6. Miscellaneous Services.

	£
Contribution to Commonwealth Agricultural Bureaux ..	49,711
Grant to Standards Association of Australia	58,500
Contribution to Chair of Aeronautics at University of Sydney (establishment and maintenance)	5,000
Grant to National Association of Testing Authorities ..	14,000
National Institute of Oceanography	6,269
Minor International Associations	1,967
Australia and New Zealand Association for the Advancement of Science	1,162
	136,609

XXXVI. ACKNOWLEDGMENTS.

In various sections of this Report reference has been made as in previous years to the valuable assistance afforded by many State Departments, Universities, and other organizations and individuals. The Organization desires to express its gratitude for the help given by these bodies and persons in providing laboratory accommodation and other facilities and in many other ways. The Organization also wishes to acknowledge the assistance which it has received from its Committees, the members of which have placed their knowledge and experience so freely at its disposal.

F. W. G. WHITE, Chairman.
S. H. BASTOW
R. N. ROBERTSON
A. W. COLES
J. MELVILLE
} Executive.

15th October, 1959.

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